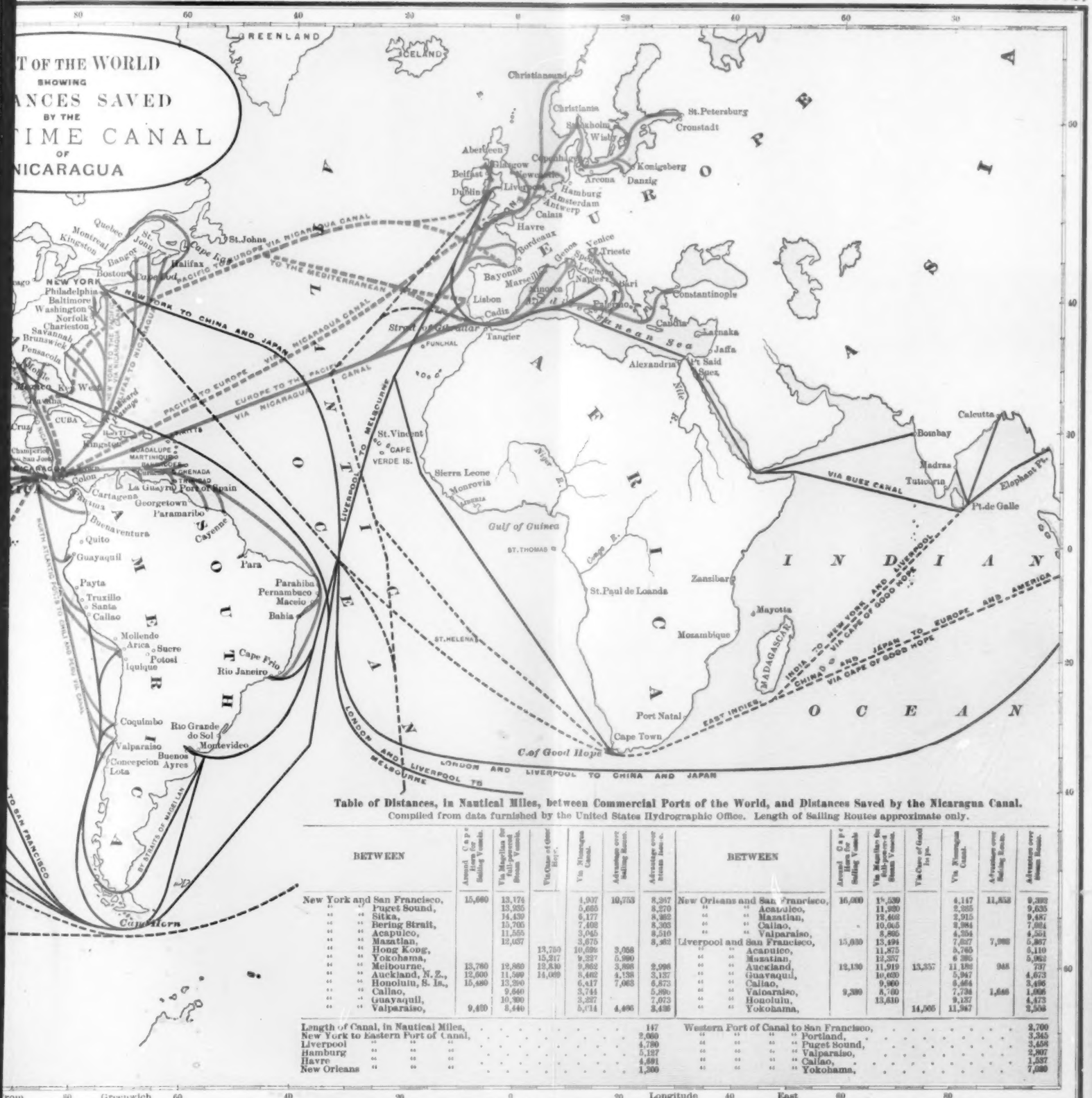

Table of Distances, in Nautical Miles, between Commercial Ports of the World, and Distances Saved by the Nicaragua Canal.

Compiled from data furnished by the United States Hydrographic Office. Length of Sailing Routes approximate only.

BETWEEN	Around Cape Horn for Sailing Vessels.	Via Magellan Str. for full-powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Routes.	Advantage over Steam Routes.	BETWEEN	Around Cape Horn for Sailing Vessels.	Via Magellan Str. for full-powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Routes.	Advantage over Steam Routes.
New York and San Francisco,	15,660	13,174		4,937	10,753	8,267	New Orleans and San Francisco,	16,000	13,539		4,147	11,853	9,392
" " Puget Sound,		13,235		5,005		8,270	" " Acapulco,		11,920		2,385		9,535
" " Sitka,		14,439		6,177		8,262	" " Mazatlan,		12,462		2,915		9,487
" " Bering Strait,		15,705		7,402		8,303	" " Callao,		10,065		2,984		7,081
" " Acapulco,		11,555		3,045		8,510	" " Valparaiso,		8,805		4,254		4,551
" " Mazatlan,		12,037		3,675		8,362	Liverpool and San Francisco,	15,030	13,494		7,627	7,403	5,867
" " Hong Kong,			13,750	10,698	3,052		" " Acapulco,		11,875		5,765		6,110
" " Yokohama,			15,217	9,227	5,990		" " Mazatlan,		12,357		6,395		5,962
" " Melbourne,	13,760	12,860	12,510	9,862	3,898	2,998	" " Auckland,	12,130	11,919	13,357	11,189	948	737
" " Auckland, N. Z.,	12,600	11,589	14,069	8,462	4,138	3,127	" " Guayaquil,		10,630		5,947		4,673
" " Honolulu, S. Is.,	15,480	13,290		6,417	7,063	6,873	" " Callao,		9,900		6,464		3,436
" " Callao,		9,640		3,744		5,896	" " Valparaiso,	9,580	8,760		7,734	1,846	1,026
" " Guayaquil,		10,300		3,227		7,073	" " Honolulu,		13,810		9,137		4,673
" " Valparaiso,	9,460	8,440		5,774	4,686	3,436	" " Yokohama,			14,506	11,947		2,508

Length of Canal, in Nautical Miles,		147	
New York to Eastern Port of Canal,		2,060	
Liverpool " " "		4,780	
Hamburg " " "		5,127	
Havre " " "		4,491	
New Orleans " " "		1,300	
Western Port of Canal to San Francisco,			2,700
" " " " Portland,			3,345
" " " " Puget Sound,			3,458
" " " " Valparaiso,			2,807
" " " " Callao,			1,537
" " " " Yokohama,			7,020

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIV. JULY, 1892. NO. 1

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THE NICARAGUA CANAL.

BY GEO. W. DAVIS,
General Manager Nicaragua Canal Construction Company.

[*A lecture delivered before the Franklin Institute, January 8, 1892.*]

Mr. Davis was introduced by Dr. Wm. H. Wahl, Secretary of the Institute, and spoke as follows:

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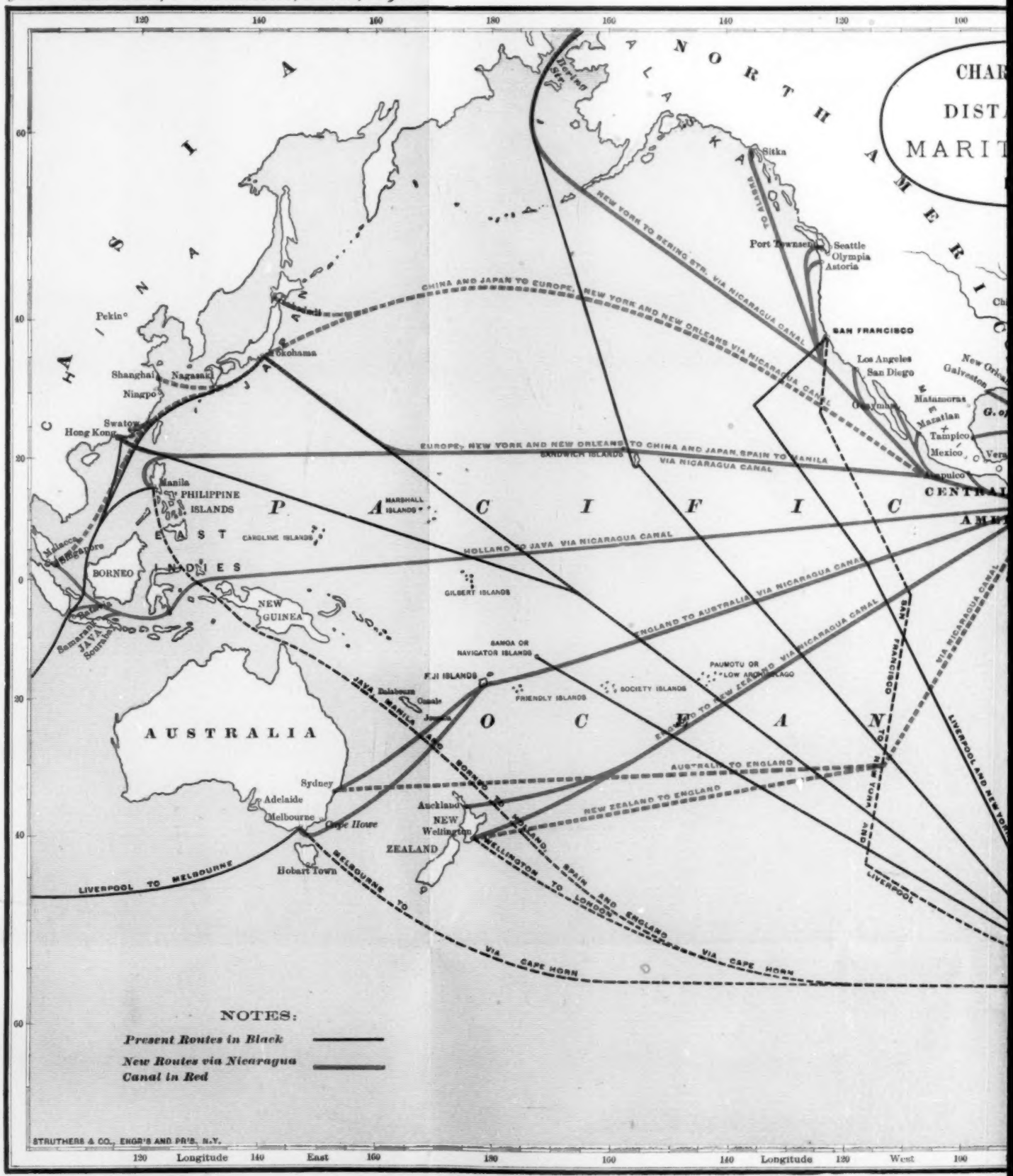
With the subject chosen for this night's address, or the broader one of inter-oceanic communications in general, you are already familiar. I recall that my friend Admiral Ammen read a paper on this subject before this Institute some two years since, and I have interpreted your wish to be, to hear from me something pertinent to the present aspects of the problem of joining the two oceans, rather than to traverse


CHAR
DIST
MARIT
NORTH AMERICA
ASIA
PACIFIC OCEAN
AUSTRALIA
Sitka
Port Townsend
Seattle
Olympia
Astoria
SAN FRANCISCO
Los Angeles
San Diego
Pekin
Yokohama
Shanghai
Nagasaki
Ningpo
Swatow
Hong Kong
Manila
PHILIPPINE ISLANDS
MARSHALL ISLANDS
CAROLINE ISLANDS
EAST INDIES
BORNEO
NEW GUINEA
GILBERT ISLANDS
SAMOA OR NAVIGATOR ISLANDS
FIJI ISLANDS
FRIENDLY ISLANDS
SOCIETY ISLANDS
PAUMOTU OR LOW ARCHIPELAGO
Sydney
Adelaide
Melbourne
Cape Howe
Hobart Town
Auckland
NEW ZEALAND
Wellington
Acapulco
Mexico
Tampico
Matamoras
Mazatlan
CHINA AND JAPAN TO EUROPE, NEW YORK AND NEW ORLEANS VIA NICARAGUA CANAL
NEW YORK TO BERING STR. VIA NICARAGUA CANAL
EUROPE, NEW YORK AND NEW ORLEANS TO CHINA AND JAPAN, SPAIN TO MANILA VIA NICARAGUA CANAL
HOLLAND TO JAVA VIA NICARAGUA CANAL
ENGLAND TO AUSTRALIA VIA NICARAGUA CANAL
AUSTRALIA TO ENGLAND
NEW ZEALAND TO ENGLAND
LIVERPOOL TO MELBOURNE
MELBOURNE TO LIVERPOOL VIA CAPE HORN
WELLINGTON TO LONDON, SPAIN AND ENGLAND VIA CAPE HORN
LIVERPOOL AND NEW YORK VIA NICARAGUA CANAL
SAN FRANCISCO TO NEW YORK
NOTES:
Present Routes in Black
New Routes via Nicaragua Canal in Red
STRUTHERS & CO., ENGR'S AND PR'S, N.Y.
Longitude East
Longitude West

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the ground already covered by those who have preceded me.

At the time Admiral Ammen read his paper on "Isthmian Canal Routes," December, 1889, the world had just learned of the collapse of the Panama bubble, although assurances from Paris of speedy resumption of work were afterwards heard. The untimely and lamented death of Captain Eads had occurred shortly before, and the ship railway project has since had no advocates sufficiently able to keep it before the public.

An eminent man, one of the most illustrious of the century, having joined the waters of the Mediterranean and the Red Sea by a sea-level canal at Suez, asserted that by no other than a similar means of transit at the Isthmus of Panama could the demands of commerce be satisfied. He declared that the work at the last-named locality would be "easier to begin, to finish and to maintain than the Canal of Suez;" and straightway hundreds of millions of money, even double the sum he demanded at first, were thrust upon him. After the expenditure of vast treasure and the sacrifice of thousands of human beings, but a small portion of the total cube to be extracted had been moved, and not only was the problem itself still unsolved, but it had become manifest at last that there had been no proper appreciation from the outset of the nature and value of its factors.

Another great man, having gained well deserved fame and prestige by the execution of engineering works of vast value to the nation and people, boldly proposed the novel idea of wheeled transportation over Tehuantepec of the largest deep-sea vessels. The brilliant reputation gained by this engineer in the opening of the Mississippi to deep-sea vessels, and in the execution of other very important works, secured to Captain Eads an attentive hearing, and for many years his scheme had many supporters. Most earnest efforts were made to secure Government aid for the project, and he endeavored to launch the enterprise as a private undertaking, but the world looked upon the scheme as a colossal experiment and his attempts failed utterly, the common

sense of mankind proving in this instance a safer guide than the confident assertions of a sanguine enthusiast.

The use of locks at Suez was unnecessary, and at Panama was at first declared inadmissible because of inevitable delays incident to the raising and lowering of vessels from one level to another. When the sea-level plan of construction at this locality was resolved upon, there was no precedent that could be cited in refutation of the argument advanced, but before the work at Panama had come to a standstill, the world had learned that the impediment to rapid transit of deep-sea vessels occasioned by locks was of very small moment, for at Sault Ste. Marie a lock almost as large as any required on the Isthmus had been passing vessels daily by the score up to 3,000 tons capacity. The English had already entered upon the construction of the Manchester Ship Canal, having spent several years in studies and surveys, and the most careful consideration of all existing methods of overcoming the difficulties. Among others, Captain Eads was called in as a consulting engineer, and the plan of a sea-level canal throughout from Liverpool to Manchester had many earnest and able advocates, but the lock system was finally adopted and the work is now almost completed. In another year the *Etruria* and *Teutonic* may discharge and load at the Salford Docks if it should be desired, and, locking down sixty feet, reach the sea some thirty-five miles away in less than six hours. Confronted with such demonstrations of the falsity of his reasoning, M. de Lesseps at last withdrew his objections to the lock, but collateral difficulties at Panama of almost insurmountable magnitude confronted him; besides the canal proper, he was obliged to provide two other artificial channels, of capacity adequate to conduct to the sea the entire drainage —tributary to the Chagres on either hand—of the flood waters that have been known to raise the level of that stream fifty feet in a few hours, producing veritable cataclysms that flood the whole valley all the way from the foothills to the sea. Confronted with these colossal besetments, being compelled to admit the false premise on which his plans were based, the people of France, becoming informed

as to the true conditions, refused further advances of funds, the inevitable collapse came, and now the courts of his country are endeavoring to fix the responsibility for the disaster.

It may be that some time in the future the inventive genius of mankind will devise methods for the economical transportation of loaded ships overland, but as yet these plans only exist in theory and must so remain until practical experiment has given a demonstration. Must the pressing demands of ocean commerce—supplied so readily at Suez, at Manchester, at Amsterdam and at Sault Ste. Marie—remain unfulfilled at the American Isthmus until the theories become realities, or shall the barrier be pierced and the seas united by means known to be entirely adequate to all requirements of safety, economy and efficiency—means that have been in constant use from the day when, more than 400 years ago, da Vinci built in Lombardy the first lock of which we have record?

The failure of others to achieve elsewhere the impossible should not restrain us from an effort to overcome the barrier that separates the two oceans, if the work is within the limits that always hedge commercial enterprises. The questions are therefore proper: What do we know of the magnitude of this undertaking, what the means required, what the time needed for its accomplishment and what its measure of usefulness?

I shall not detain you with an account of the efforts of the early navigators to discover "The Secret of the Strait," nor shall I allude to the surveying expeditions sent out by governments and individuals during the last half-century with the object of locating the spot where the difficulties are least forbidding. All this is a matter of history familiar to you and not pertinent to my subject, but it is of moment that some account shall be given of the steps taken to elucidate the problem at Nicaragua, for unless our knowledge be sufficient to enable us to value all the difficulties, we are deserving the same reproach that justly came home to M. de Lesseps—namely, that we entered upon the work of construction before we fully understood the magnitude of

the task. We cannot hope to interest capital, unless we can convince the ablest engineers and financiers of the practicability of our project, and we know that before the money will be forthcoming the ground must be examined, the plans studied, the measurements verified, and the estimates in all their parts justified, for in the launching of the Nicaragua project there can be no repetition of the spectacle that attended the presentation of the Panama scheme—the outpouring of a nation's wealth with no other security than the prestige of a great name.

The American solution of the problem of inter-oceanic communication has moved less rapidly but more surely on its way, as a full and intimate knowledge of its characteristics has been obtained, and it now commands public attention and confidence with constantly increasing assurance of ultimate success. The physical features of the lake and river route by Nicaragua have been carefully and minutely studied in all their relations, and have been made the subject of plans thoroughly elaborated in all details, and of estimates as thoroughly and carefully calculated. Every doubtful or difficult feature has been closely scrutinized and competent engineers pronounce the project unembarrassed by any difficulty save that of magnitude, which in this age is a hindrance only when it advances the cost of construction beyond the limit of remunerative returns.

I will sketch very briefly the means employed to supply the information that is felt to warrant the confident assurance I have just uttered.

EARLY SURVEYS.

For the first complete instrumental survey of the Nicaragua route, one that responds to the demands of engineering science, we are indebted to a citizen of Philadelphia, Mr. Oliver W. Childs, who in 1849–50 examined the whole route and pointed out the least depression that anywhere exists in the American Cordillera, from Alaska to Patagonia. The general accuracy of Mr. Childs' work has been fully confirmed by all subsequent examinations. The Government

survey of Lull-Menocal in 1872–73 was the next instrumental survey, and in the judgment of the Commission appointed by the President, at whose head was the Chief of Engineers of the Army, this was sufficient to demonstrate its superiority to all other routes from Tehuantepec to Darien.

In 1876–77, Mr. Menocal, while engaged upon civil work in Nicaragua added largely to existing knowledge regarding the topography near Greytown. In 1880, he also made a re-survey of the western division of the route—this by orders of the United States Government—and by the same authority in 1885 the same officer conducted very extensive examinations, looking to the divergence of the line from the San Juan River where it leaves the hills, and so to the avoidance of grave difficulties of drainage and maintenance, inevitable if the Childs' and Government location were followed all the way to the sea.

SURVEYS FOR LOCATION.

In 1887, the present concession for the utilization of this route was granted by the Government of Nicaragua to the agent of the present company, and in the autumn of the same year the work of final survey was begun under the direction of Mr. Menocal (who had been appointed Chief Engineer), and was uninterruptedly prosecuted, so that by the close of the year 1888 these definitive surveys for location and construction had been substantially completed, permitting the preparation of plans for building and the detailed estimates of cost.

The first corps of engineers despatched consisted of forty-five persons for technical work and 100 laborers, and was reinforced from time to time as occasion required. They were organized into six land surveying parties, one hydrographic party and two parties equipped for earth and rock borings. They re-located the entire canal line and acquired the most minute information concerning its every physical feature. In this connection I must call to your attention this fact which I think worthy of note, that while the length of artificial canal is less than thirty miles, the total length

of lines actually surveyed by transit and level in cross-sectioning, location of locks, dams, embankments, railroads, flowage lines, etc., is not less than 4,000 miles.

Upon the open, unprotected sea-beach in front of the Greytown lagoon—which was the former capacious harbor of San Juan del Norte—all supplies had to be landed, and this, in itself, was a very serious and expensive operation, for the vessels had to lie at anchor in the open roadstead two miles from land, where they were almost constantly exposed to the northeast "trades." These winds here usually have a velocity of ten to twenty miles an hour, and of course produce a violent surf, which had to be passed through in each trip between ship and shore. So difficult and tedious was the landing of cargoes there during the earlier operations before the opening of the harbor, that it was no uncommon occurrence for vessels laden with only ordinary packages of goods to depart without discharging their freight.

At first it was attempted to shelter the men in tents, but experience soon showed that canvas was neither an economical nor suitable protection. During all the surveying and other preliminary work inland, and even up to the present time, the workmen of all classes have lived in temporary huts, thatched with palm leaves, and many thousands of dollars have been expended for labor (there was no other outlay) on such structures.

The surveys were necessarily slow and expensive, for they were prosecuted in a tropical forest, where nothing could be seen at a distance of fifty feet, and where every step had to be preceded by the blow of a *machete* to clear away the tangled mass of vines and other vegetation that everywhere obstructed progress. The country along the line from San Juan to Ochoa was entirely without highways or other means of communication, except in a few localities, where navigation of the small streams was possible by canoes after clearing the water-courses from logs, stumps and other obstructions. From the small coast settlement of San Juan, where all supplies were landed and stored, all the way to Ochoa, a distance of thirty miles, the method of

transport of provisions and all other supplies, except in the restricted localities where canoes could be used, was similar to that employed by explorers in the heart of Equatorial Africa, viz: packs of suitable weight borne on the shoulders of men, up and down hills, so steep that support in climbing must be had from the brushwood or trees, much of the time with the rain pouring in torrents; through marshes and swamps where for long stretches the men had to flounder along in water and mud waist-deep, and this through a wilderness as wild and trackless as that about the head-waters of the Congo. No description can give an accurate idea of the tediousness, difficulty and weariness of this task.

The Government and other surveys by Childs and Menocal previous to 1886 had sufficed to demonstrate the feasibility of the general line of the San Juan River and Lake Nicaragua from Greytown to Brito for the Inter-oceanic Ship Canal route, but the present company, appreciating the importance of ameliorating, if possible, the difficulties to be encountered, could not properly omit the most careful investigations of very extended adjacent areas, in the hope of revealing an improved location in whole or in part. While the Government survey of 1872 served to demonstrate the entire practicability of the Nicaragua route, it will be interesting to know that of the line as now located between the Atlantic and the San Juan River, at San Carlos mouth, and also between the Pacific and Lake Nicaragua, a total distance of forty-nine miles, but about eight and one-half miles coincides with the Government route of 1872.

The Government survey of 1885 proved the superior advantage of a line diverging from the San Juan River near the mouth of the San Carlos, over the earlier location in the San Juan Valley, but the execution of the work on this route, remote from the river, involved the piercing of a ridge or spur of hills at a point which was some 500 feet high, unless a lower and practicable pass could be found, but the dense forest prevented an easy determination of this point. The passage across this ridge was but two or three miles long, yet in order to eliminate all doubt, and make certain

that no improvement was possible, it was necessary to examine the whole watershed and the approaches thereto for many miles on either bank, to meander every neighboring creek and rivulet to their origin on the Divide; in fact, to examine about every square rod of this highland, so as to permit the accurate plotting of all the information and the correct representation of all the topographic details on charts that could be studied at leisure.

Therefore, it is that the examinations have covered not only the one line first selected, but any and all routes that presented any indications of practicability. So, too, has it been necessary to explore every range of neighboring hills, and every small stream, in order to determine the limits and area of basins drained by streams flowing to or across the line. The Costa Rican bank of the San Juan River was critically examined from Rio San Carlos to the Colorado bifurcation, in the hope—which finally proved delusive—of finding a practicable site for erection of a dam twenty miles below Ochoa, that would permit the avoidance altogether of the ridge before mentioned, and the location of the line from the supposititious site of the dam at Point Sarapiqui through the San Juanillo valley to the port at San Juan del Norte; but the whole country on the Costa Rica bank of the river back for several miles was found low and flat, intersected with creeks and lagoons, forbidding the further consideration of the alluring suggestion of inundating the lower San Juan, and so saving many millions of expense in heavy rock cuttings; but it cost much time and money to ascertain that this idea, which had been urged by some intelligent men, was impracticable.

So soon as the first corps of engineers was landed, the surveying parties were organized and at once pushed out. Traversing the lowlands for a few miles back of Port San Juan, were some sluggish streams whose courses favored the idea of utilization for water-borne carriage of supplies. A steam snag boat was immediately set at work removing the obstructions, and barriers too heavy and massive for displacement otherwise were broken up with dynamite. The San Juanillo and Deseado were thus cleared and utilized

for a distance of upwards of thirty miles of their course, but the streams were so crooked that the actual land mileage accomplished was only about one-third the distance by water. The trails for the packers were cut out, foot bridges built across impeding streams and ravines, so that supplies could be transported with certainty, though slowly, to and beyond the Eastern Divide.

The San Juan River has long been used by a steamboat transportation company, and a large part of the produce of Nicaragua has for forty years been moved from the interior by this route. Steam transport *via* the river was, of course, availed of by the engineers when it served their needs, but much of the surveying work was remote from the river, and hence its unavailability, except in the region beyond the Divide toward Ochoa, where the canal and river were in closer proximity. As will be seen by reference to the map, the canal line beyond the dividing ridge intersected the valleys of the San Francisco, Chanchos and Danta. The channels of these streams were also cleared and made available for canoe traffic from the San Juan River. Numerous camps and depots of supplies were constructed and stocked wherever necessary, and fleets of light steel canoes were employed as means of communication and supply.

The idea was early entertained of utilizing the channel of the San Juan River for slack water canal navigation, and thus making it serve as a portion of the inter-oceanic ship transit route. Childs, in 1851, demonstrated its suitability for such use and the Government survey of 1872 confirmed the earlier observations and deductions, but in both these projects it was proposed to construct at each of the principal rapids, dams and locks of low lift, and thus to convert the stream into a series of pools or reaches. The general level of the canal at any point would, therefore, conform closely to the natural level of the river. Such a treatment of the problem would have precluded the shortening of the line and reduction of the expense gained by the adoption of the nearly direct "overland route" from this point to the sea. The excavation involved in passing from Rio San Carlos,

through the Eastern Divide at the natural level of the waters in the river, would have demanded double the work and expense that should suffice if the "lake level" were extended to the San Carlos, and maintained all the way through the eastern dividing ridge as is now proposed.

The confident belief was early expressed by the Chief Engineer that a series of low dams in the upper San Juan was not the best treatment, for he believed the "lake level" could be maintained to or below the junction of the San Carlos, and so the rapids in the river could be all submerged, but he realized that this treatment would demand, as a *sine qua non*, the erection and maintenance of a massive dam—across the main stream near the point where the canal diverged—high enough to raise the water level at its site to that proposed for the lake itself; in other words, the dam had to be high and strong enough to hold back the flow of this powerful river when its level should be raised fifty-six feet. It was soon ascertained that the natural conditions, at a place named Ochoa, were favorable as to the width of stream, character of bottom and solidity of abutments, for the erection of such a dam, but on further examination of Costa Rican territory it became necessary to make sure that the waters when so raised would not escape through the hills and lowlands bordering the river on this bank. Surveyors spent many weeks in the investigation, and secured exact information that fortunately proved the feasibility of the plan of embaying the waters of the river, and converting its valley into an extension of the lake, upwards of sixty miles in length.

The information collected by former expeditions in regard to the topography west of the lake, was so complete that to elucidate the problem of quantities and cost, less new surveying work was there required than along the eastern divisions. Nevertheless, the whole line was re-surveyed, and the additional information thus secured enabled the engineer to introduce important changes and improvements in location and plans of construction, that could not be embraced in the earlier designs.

Every stream whose valley was to be utilized in whole or

in part was thoroughly examined or traced in many cases to its source, its flow at high and low water was gauged and every question connected with water supply and disposal of surplus discharge was carefully studied.

But the work of the surveyor was not ended with the completion of these examinations of the ground. It was impossible to classify the material to be removed and assign a cost per unit, until exact knowledge was had of the nature of the concealed strata in all localities where excavations would be required. So the surveyors for "final location and construction" had to be equipped, not only for obtaining an accurate knowledge of the surface of the earth, but as well of the strata beneath the surface. For this purpose a boring and drilling equipment was provided, with which, at the site of all important works, such as dams, embankments and locks, as well as at the points where heavy cuttings will be required, subterranean examinations have been made in great numbers. Earth augers were used where there was no rock, and when this was encountered the annular diamond drill was used, and cores of the rock itself brought up and preserved for future reference and examination by engineers and contractors proposing to submit tenders for work. Owing to the transportation difficulties, steam drills were impracticable and the work was accomplished with hand-power.

THE ROUTE AND PROPOSED CANAL.

Probably some description of the canal itself, with the physical conditions under which it is to be built, would not be inappropriate at this time. Briefly, then, the distance from Greytown upon the Atlantic Coast, to Brito, upon the Pacific, is 170 miles, of which, however, a little less than twenty-seven miles is actual canal in excavation; the remainder of the distance is free navigation in the San Juan River, in Lake Nicaragua itself, and in basins formed by flooding the valleys of several smaller streams, such as the Deseado and San Francisco upon the eastern side and the Rio Grande and Tola on the western. But the key of the situation, and the one thing which renders it pos-

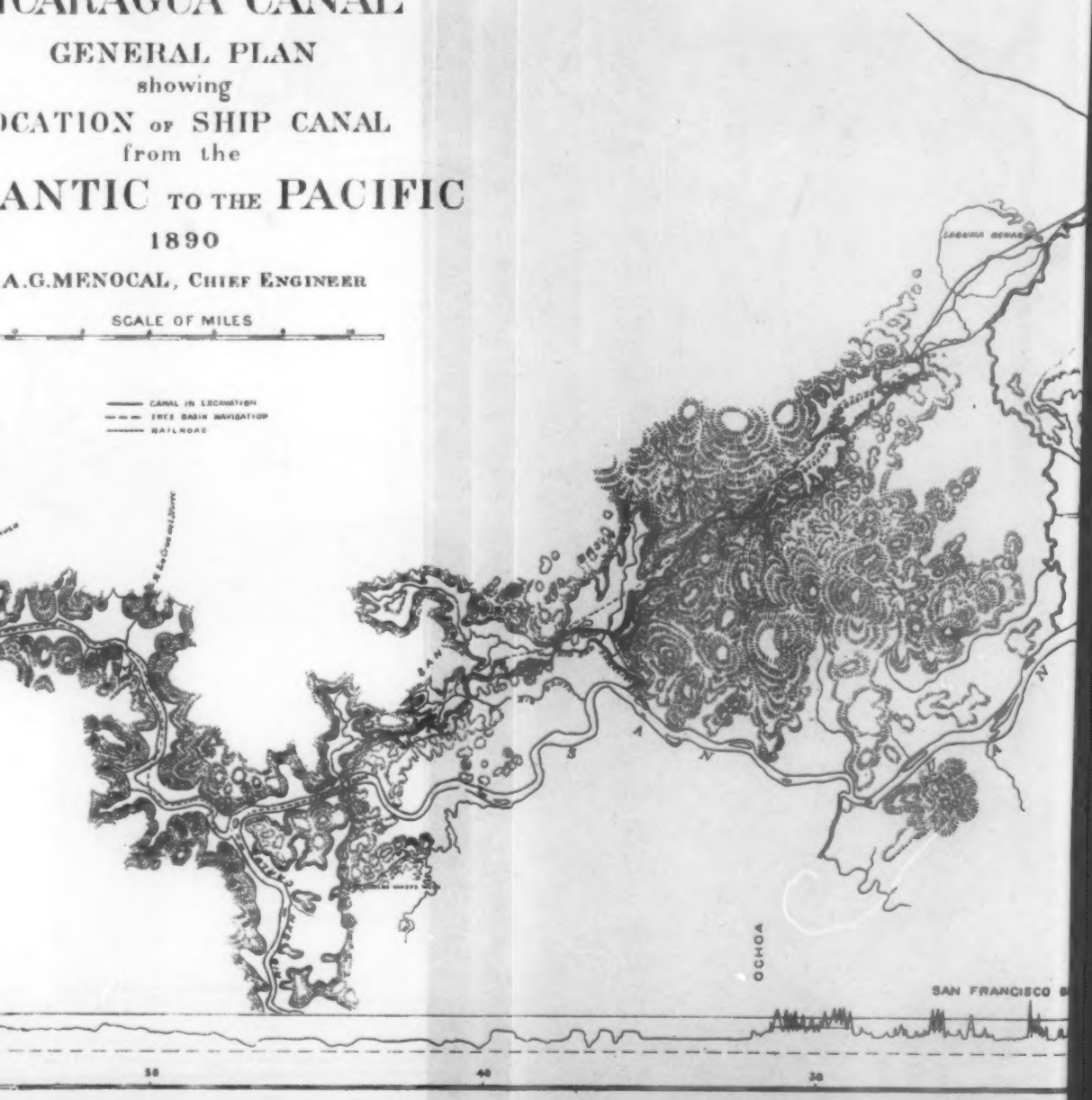
ATLANTIC OCEAN
ATLANTIC OCEAN
EASTERN DIVIDE
DESEADO BASINS
SAN FRANCISCO BASIN
OCHOA
LOCK 1
LOCK 2
LOCK 3
SAN JUAN

ICARAGUA CANAL

GENERAL PLAN
showing
OCATION OF SHIP CANAL
from the
ANTIC TO THE PACIFIC
1890

A.G.MENOCAL, CHIEF ENGINEER

SCALE OF MILES



NICARA

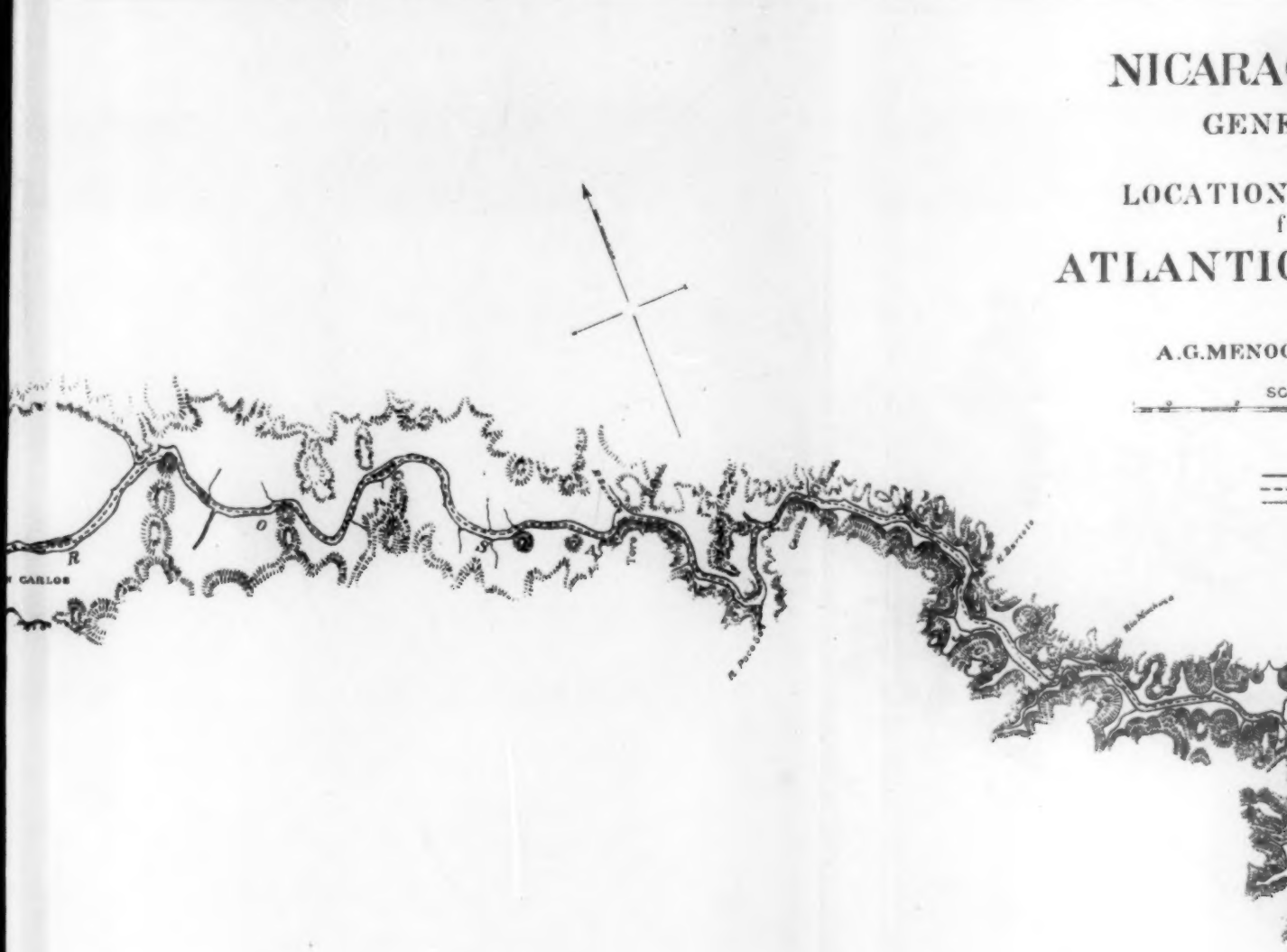
GENE

LOCATION
f

ATLANTIC

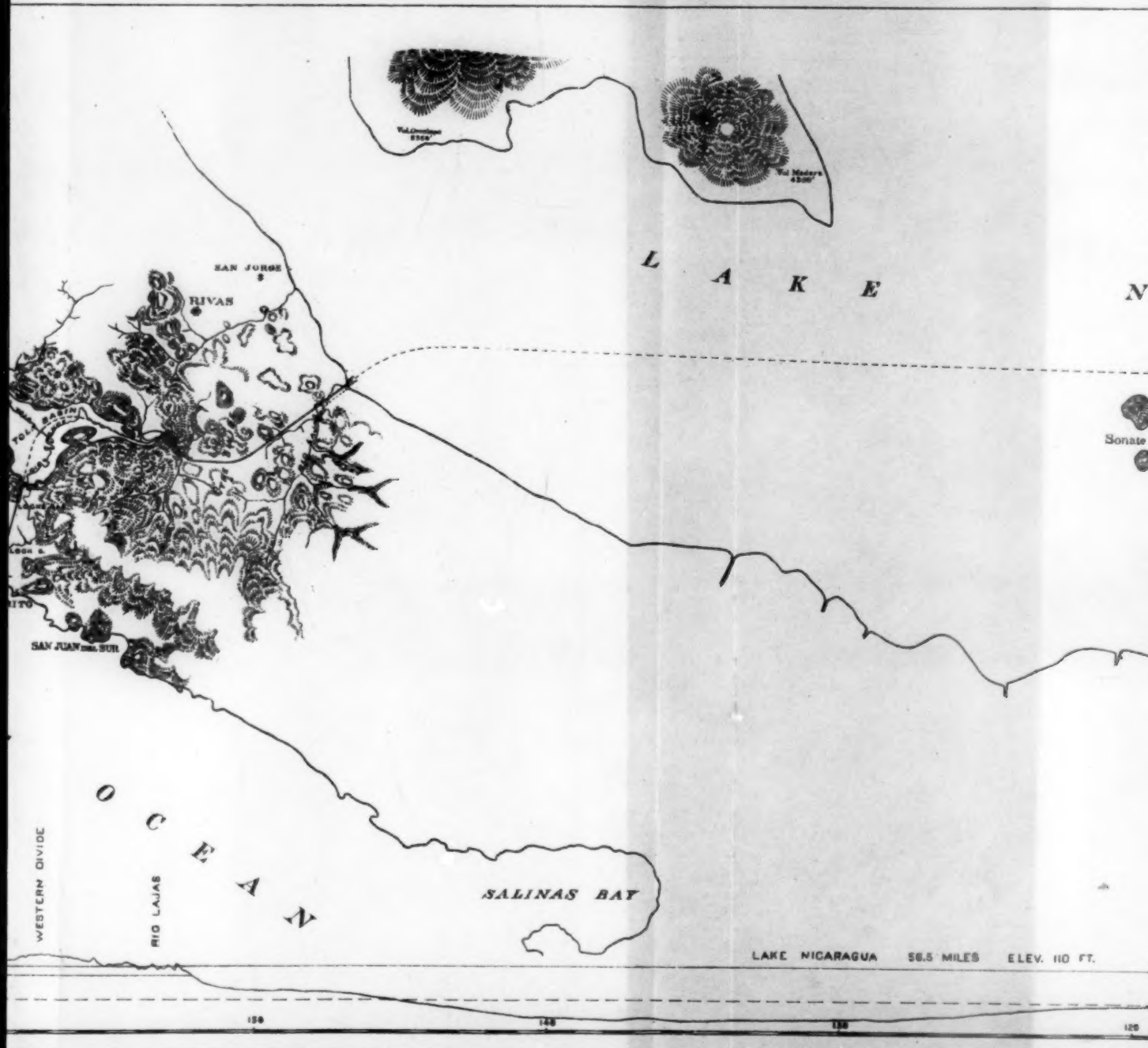
A.G.MENOC

SC



RIO SAN JUAN 64.5 MILES

N I C A R A G U A
Sonate Is.
Balsillas Is.
Solentiname Is.
Zapote I.
Pizarro I.
FT. SAN CARLOS
V. 110 FT.
125
110
100
90


SAN JORGE
RIVAS
L A K E
N
Sonate
SAN JUAN del SUR
O C E A N
SALINAS BAY
WESTERN DIVIDE
RIO LAJAS
LAKE NICARAGUA 56.5 MILES ELEV. 110 FT.
150
140
130
120

Vol Orosi
5100'
Vol Madera
4300'
L A K E
SAN JORGE
RIVAS
SUR
O C E A N
SALINAS BAY
RIO LAJAS
LAKE NICARAGUA
150
148
150

PACIFIC OCEAN
BRITO
LOCK 6
LIFT 81'6"
LOCKS 4-5
LIFT 81'
TOLA BASIN
WESTERN DIVIDE
RIO LAJAS
PACIFIC OCEAN
SAN JUAN DEL SUR
BRITO
TOLA BASIN
120
180

sible to build the canal and operate it successfully, is found in the lake itself, which is an inland sea, something like 100 miles long and 50 miles wide, and varying in depth to 240 feet. This lake, by receiving the waters which come down from the mountains into this great reservoir, prevents any sudden flood, and therefore, removes all danger to the canal from any excessive flow, which otherwise would occur. The outlet of the lake is the river San Juan, which, however, has two or three rapids, that can now only be passed by steamers at high water; during the low water period freight has to be trans-shipped around these rapids over a short tramway or carried over them in smaller boats. But the river itself is from thirty to 130 feet in depth. There is to-day plying upon the waters of Lake Nicaragua a steamer which was built at Wilmington, Del. The vessel steamed to Greytown, was taken up the river, and has been doing the entire trading business upon that Lake for eight years. That steamer, when it lies at what would be the beginning of the canal on the west side, is only twelve miles from the Pacific Ocean, and from the mast-head, if there were a mast upon it, the Pacific Ocean could be readily seen. As I have before remarked, this lake with its outlet is the key to the situation which makes the canal possible, and in fact, it seems to open out a natural course for the inter-oceanic route.

All the surveys and plans of the United States Government, were based upon following the river San Juan throughout its whole course, and rendering it navigable by removing the rapids of which I have spoken and of building several dams and locks. Whilst this plan was undoubtedly possible, our company conceived the idea that we could abandon the lower San Juan, for the first twenty-five miles, where it is very crooked and spreads out in several channels over what is really a delta, such as is found at the mouth of the Nile and of the Danube. After careful and painstaking surveys, a route was found striking directly from Greytown across the lowlands, following the valleys between the hills to a point called Ochoa, on the San Juan River and which saved at least thirty miles in distance over

that involved by following the river in all of its windings. The discovery of this route will very greatly diminish the difficulties of building and maintaining the canal, and will add very greatly to its value when completed.

For the first ten miles from Greytown the line runs directly across low ground, raised but little above the sea. Here the canal will be made entirely by dredging, which is now in progress. The soil is composed entirely of sand and clay that is easy to work, and maintains its slopes after it has been worked. The end of this section brings us to the first lock, and then the next three and one-half miles include the locks with their dams and raise the canal to the level of Lake Nicaragua. From the Divide cut the canal traverses basins which are created by damming the streams which flow across the line and whose valleys are flooded. Through these basins there is little excavation to be done. Some gaps in the foot-hills have to be closed by dams and embankments. Just beyond the third lock we come to one of the most difficult parts of the undertaking—the rock cut. Difficult, I say, because of the length of time required to take out the rock, for there is no work simpler than rock excavation, or more carefully estimated as to its final cost and the time required. This cutting is between two and three miles in length, and averages about 140 feet in depth, but much of the material taken out is to be utilized for works on the canal itself. By means of the railroad which is now building, this rock will be carried down to Greytown to be used upon the breakwater or pier; the embankments in the foot-hills will be constructed in large part from the rock taken from this cut, and at the point where we strike the San Juan River, called Ochoa, there is a dam to be constructed across the river which will hold the waters at the level of the lake. This dam also will be constructed from the rock taken from excavation. If we had not this cut we would have to procure the material from other sources of supply.

As said before, the canal goes into the San Juan River at Ochoa, and from that point to the lake, a distance of sixty-four miles, there is free navigation, the river being

of a width for the largest steamers to pass and repass each other at full speed without danger. The rapids of which I have spoken are, of course, to be deeply submerged, and the canal enters Lake Nicaragua at San Carlos. Beyond this point some dredging is to be done in soft mud to reach the required depth, and after that it is clear sailing across Lake Nicaragua, a distance of fifty-six miles, to the point where the canal leaves the lake upon the western side.

The length of the canal on the west of the lake to Brito is, by the line followed, seventeen miles. The point where the canal crosses from the lake is the lowest land in the whole range of mountains reaching from the United States down to the southern point of South America. The pass is only forty-three feet above the surface of the lake. A cut of about five miles is here to be made, leading to what is known at the Tola basin, and the average of excavation is only twenty-one feet. The canal then traverses this large basin, covering many thousand acres and of an average depth of about fifty feet. At the farther end of the basin three locks bring the canal down to the level of the Pacific Ocean at Brito. There is now only a partial harbor at Brito, and a breakwater has to be constructed there as at Greytown upon the east side. Upon the northern side of the harbor there is a natural headland of rock, which projects into the ocean a considerable distance. We build a breakwater to the south of this natural headland, and then by some dredging we secure a safe and commodious harbor.

This is a brief description of the work which has to be done. There are no unsolved problems in it. Engineers who have examined it and the practical builders who have gone over it, one and all say that it is simply a plain work. It comes down to a certain number of yards of rock to be excavated, a certain amount of earth to be removed, locks to be built, and dams to be constructed and the creation of harbors; in short, there are no physical or engineering difficulties whatever in the way. If the canal had been proposed to be built of the ordinary dimensions it could have been done for a very moderate sum, but the plan of

our company calls for the construction of a canal which will pass the largest ship afloat. The minimum depth of water is to be twenty-eight feet. The size of the locks is to be 650 feet in length and 80 feet in width, and 30 feet in depth. There is no experiment about these locks or their capacity to pass the traffic.

As I have said, there is no experiment in the construction and operation of these locks. The United States Government built the first great lock of the world; that is, at the Sault Ste. Marie, connecting Lake Superior and Lake Huron. That lock is the prototype of those we propose to build, and of the same size with the exception that ours have a greater lift. The wonderful success of the canal at the Sault Ste. Marie has induced building similar locks in other parts of the world. As to their capacity to pass commerce, I need simply to call your attention to the fact that last year, in 234 days, the time the Sault Ste. Marie lock was open for navigation, it passed nearly 9,000,000 tons of shipping, or nearly fifty per cent. more than passed through the Suez Canal. The Government of Holland is building a similar lock of these dimensions on the Amsterdam Canal. The German Government is also building four great locks of the same dimensions or larger, upon a great sea canal across the Peninsula Holstein, which is to connect the Baltic with the North Sea, thus saving a distance of 700 miles over the route around Denmark, but the work is being constructed as a matter of national defence, for it connects the naval station at Keil, upon the Baltic, with the mouth of the Elbe, upon the North Sea. This canal is over sixty-three miles in length, and the amount of excavation to be done upon it is fully equal to the excavations incurred upon the Nicaragua Canal. The world has heard little of this great work, because it is being carried on entirely by the German Government, having therefore but one stockholder; there are some 8,000 men employed upon it. The canal will be completed and opened in three or four years from the present time.

CAPACITY OF THE CANAL.

The Suez Canal has been found of inadequate capacity to supply the increasing requirements of commerce, although

nearly 7,000,000 tons passed through it in 1890. To supply these requirements and permit greater speed, its width—now seventy-two feet on the bottom—is being increased.

At Nicaragua it has been felt to be necessary to provide at first for the most ample capacity. As regards dimensions of the canal prism, provision has been made as follows:

Length. Miles.	*Width—Feet.*		*Depth—Feet.*	*Area of Cross-section Square Feet.*
	Top.	*Bottom.*		
9¾	288	120	28	5,712
2⅞	210	120	30	4,950
5⅜	184	80	30	3,673
8	80	80	30	2,400
21⅜	basins		30 and upwards	
64½	river		30 "	
56½	lake		30 "	
¾	locks		30 "	
169¾				

A speed of five miles per hour is taken as a minimum in those sections of the canal having a cross-section equal to or greater than that at Suez. It is conceded too that in the eight miles having a sectional prism of 2,400 square feet, the speed may fall to two and one-half miles per hour. In the basins seven miles per hour, in the river eight miles and in the lake ten miles are certainly practicable, for it must not be forgotten that the 100 miles at Suez have been traversed in less than fifteen hours. As regards the time required for our six lockages, I would remark that it requires eight minutes to empty the great lock at Sault Ste. Marie, and eleven minutes to fill it. The complete lockage of a 3,000-ton steamer there takes only thirty minutes and it has been done in considerably less time. We allow forty-five minutes at Nicaragua for this operation. Basing our computations on these figures, we find it will require twenty-eight hours to pass a ship from ocean to ocean through the 170 miles of canal, basins, river, lake and locks.

The water supply is ample for a business exceeding by nine times the maximum that we expect for many years to come.

ESTIMATED COST.

The total cube of earth and rock to be extracted reaches the aggregate of slightly above 70,000,000 cubic yards.

Of this 34½ million yards of dredging are estimated at 20 cents; 5⅛ million of same material at 30 cents; 15½ million yards of earth excavation at 40 cents, and ¼ million at 50 cents; 6½ million of rock excavation at $1.25; 7 million yards of same at $1.50 and ½ million sub-aqueous rock at $5.

In embankments nearly 10,000,000 yards of material will be needed. The estimated cost of depositing this in place is taken at prices varying from twenty cents to $1.50 per yard.

Of masonry, over 634,000 cubic yards will be required. This will be principally of concrete; all the ingredients except cement are at hand. This is assumed to cost in place from $6 to $10 per cubic yard. It is also provided that the banks of the canal in many stretches shall be revetted with stone laid on the earth slopes and 264,000 yards are provided for at a cost of $2 per cubic yard for transportation and placing.

For land clearing $350,000 are allowed and forty-five miles of railroad at $60,000 per mile, and eighty miles of telegraph line at $500 per mile. For lock machinery, etc., nearly $2,000,000 are allowed. Appropriate amounts are also set aside for electric lighting, buoying of the whole canal line, light-houses at the termini and beacons. In fact, every expense that can enter into the construction has been anticipated and costs allowed.

The following is a recapitulation of Mr. Menocal's estimates, corrected to January 31, 1890:

RECAPITULATION.

Eastern Division,	$23,686,048 30
San Francisco Division,	5,163,318 10
Lake and River Division,	5,692,556 70
Western Division,	17,525,417 45
	$52,067,340 55
Surveys, hospitals, shops, management and contingencies, 25 per cent.,	13,016,835 45
Grand total,	$65,084,176 00

Early in the year 1889 the engineering estimates, plans and all official data that had been previously collected, and that had a bearing upon the technical question were submitted to a board of distinguished civil engineers for their revision and opinion.

The gentlemen referred to were:

Mr. John Bogart, State Engineer, State of New York.

Mr. E. T. D. Myers, Railroad Engineer, Richmond, Va.

Mr. A. M. Wellington, editor *Engineering News*, of New York.

Mr. H. A. Hitchcock, Prof. Engineering, Dartmouth College.

Mr. Charles T. Harvey, former Chief Engineer, St. Mary's Falls Locks.

All are well-known and distinguished in their profession. The report of these gentlemen is an exhaustive document, going at length into all the details. They give their reasons in full for increasing some of the estimates submitted and make a much larger contingent allowance than did Mr. Menocal. They estimate the total cost of the work at $87,799,570.

Other engineers of high repute have examined all our data, which are very voluminous, and contracting engineers have also submitted proposals for different sections or divisions of the work after a careful and minute inspection of the whole line. A contracting firm of entire competence and responsibility stands ready to contract for all the work required west of the lake, for a sum within our engineers' estimate.

The work is projected as a private enterprise, and we are well aware that other expenses, which the engineers cannot take into account, must be provided for; such as commissions for raising the required capital, interest on the several amounts paid in during construction and accruing before the line can earn dividends. We base our calculations on a total expenditure of all kinds—to be incurred before the route is opened for traffic—of $100,000,000, which is substantially what the Suez Canal cost.

The time required for the execution of this great work,

which is, perhaps, the most important undertaking yet remaining for our race to accomplish, is estimated at six years by conservative engineers who have studied carefully every physical question connected with it.

[*To be continued.*]

THE DEVELOPMENT OF AMERICAN ARMOR-PLATE.

BY F. LYNWOOD GARRISON.

[*Concluded from vol. cxxxiii, p. 453.*]

THIRD DAY, JANUARY 13, 1892.

Both plates tested on this day were made by Carnegie, Phipps & Co. One of them was a low-carbon steel plate and the other was high-carbon nickel-steel, both treated by the Harvey process. The plates corresponded in their chemical composition with two plates from the Bethlehem Iron Company tested in the former trials. Their value for comparative purposes was somewhat lessened by the fact that neither was up to the proper dimensions. They should each have been 10½ inches thick with a superficial area of 8 x 6 feet. The steel plate was warped in tempering, and in order to get a flat surface for securing it to the backing it was planed down so that its thickness at the sides was reduced about an inch. The reduction at the points of impact was not so great. The nickel-steel plate was cracked at one end, and about twenty inches were cut off, reducing it almost to a square. Owing to this reduced area, but four shots were fired at it instead of five, as at the other plates. Three six-inch shots were fired so as to form an isosceles triangle with its apex two feet below the centre of the upper edge of the plate, and the base angles two feet from the bottom and two feet from the right and left-hand sides, respectively. The fourth shot was from the eight-inch gun at the centre of the triangle. The points of impact on the steel plate were the same as in the six plates previously tried—a six-inch shot at each corner and

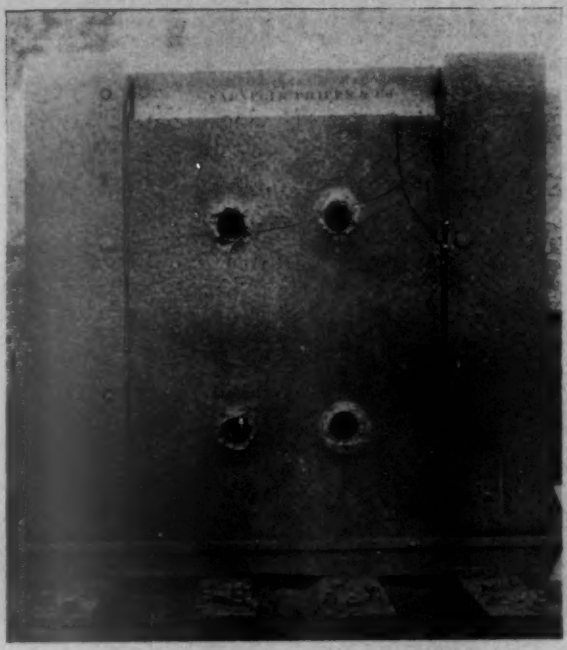


FIG. 23.—Harvey low-carbon steel, Carnegie.

FIG. 24.—Harvey low-carbon st

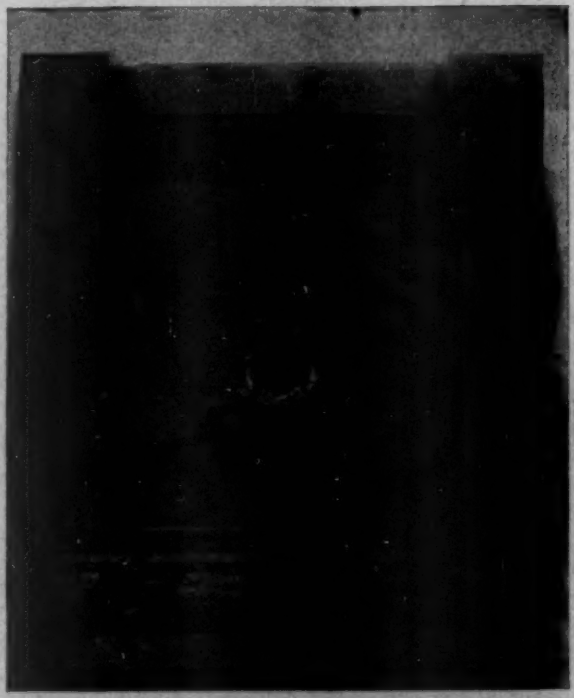
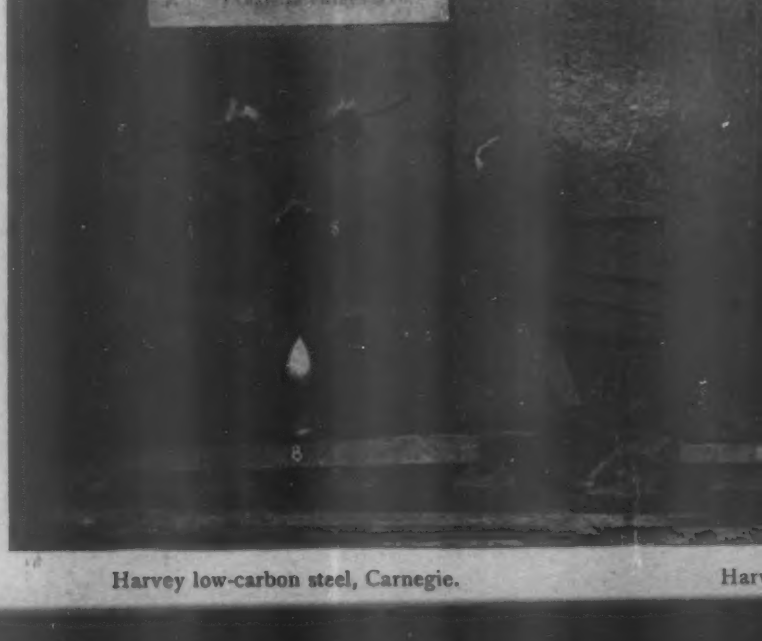


FIG. 27.—Harvey high-carbon nickel steel, Carnegie.

arvey low-carbon steel, Carnegie.

FIG. 26.—Harvey high-carbon nickel steel, Carneg

FIG. 29.



Harvey low-carbon steel, Carnegie.

Har

el steel, Carnegie.

FIG. 28.—Harvey high-carbon nickel steel, Carnegie (back).

G. 29.

Harvey high-carbon nickel steel, Carnegie.

ey high-carbon nickel steel, Carnegie (back).

kel steel, Carnegie.

an eight-inch shot at the centre. All the conditions of the trial were as before.

Round 1.

The first shot was at the upper right left corner of the steel plate, which was completely perforated, with a total

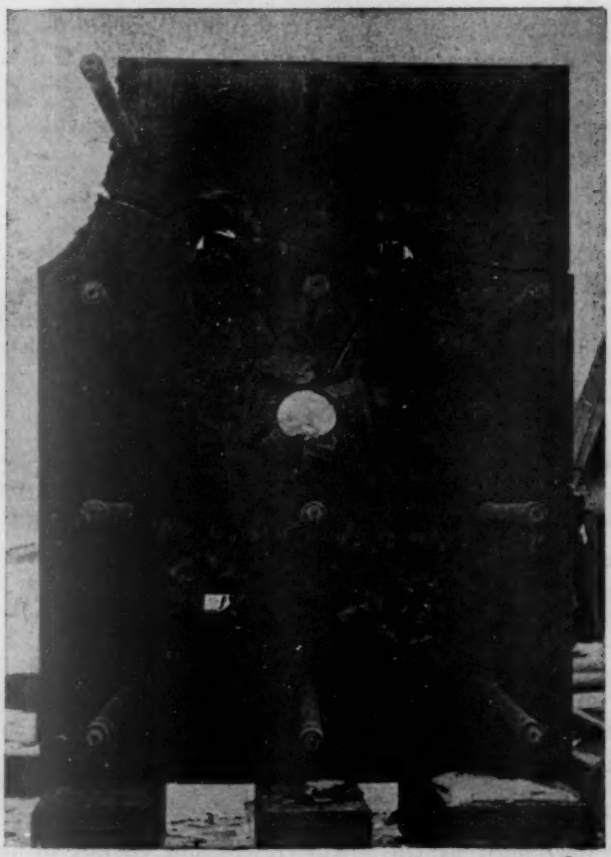


FIG 25.—Harvey low-carbon steel, Carnegie (back).

penetration of thirty-nine and one-half inches. The plate was not cracked. (*Figs. 23, 24, 25* and *29.*)

Round 2.

First shot at the apex of the triangle in the nickel-steel plate. The projectile penetrated eleven and one-half inches,

and rebounded slightly broken, leaving an irregular hole from which chips of metal flew over the bomb-proof and far out into the Potomac River. No cracks were visible. (*Figs. 26, 27, 28* and *29.*)

Round 3.

Second shot at the upper right-hand corner of the steel plate. It penetrated thirty inches in the plate and backing, and cracked a triangular piece off the upper right-hand corner of the plate with a crack connecting this fracture with the shot hole. (*Figs. 23, 24, 25* and *29.*)

Round 4.

Second shot at the lower right-hand angle of the triangle on the nickel-steel plate. It penetrated thirteen inches, leaving another ragged hole from which there was another shower of chips. There was still no crack in this plate. (*Figs. 26, 27, 28* and *29.*)

Round 5.

Third shot at the lower left-hand corner of the steel plate, and penetrated thirty-five inches in the plate and backing. The previous cracks were widened, and a new crack developed between the two upper shot holes. (*Figs. 23, 24, 25* and *29.*)

Round 6.

Third shot at the lower left-hand angle of the triangle on the nickel-steel plate. It penetrated eleven inches and remained intact in the shot hole. A slight crack extended to the side of the plate. (*Figs. 26, 27, 28* and *29.*)

Round 7.

Fourth shot at the lower right-hand corner of the steel plate. It penetrated the plate and backing forty-three inches, and a new crack was opened up from the upper left-hand hole to the left edge. (*Figs. 23, 24, 25* and *29.*)

Round 8.—Eight-inch Gun.

Fifth shot at the centre of the steel plate. It went clear through the plate and backing, struck the sand bank behind

them and glanced over. It was picked up uninjured. (*Figs. 23, 24, 25* and *29.*)

Round 9.—Eight-inch Gun.

Fourth shot at the centre of the nickel-steel plate, which had been so weakened by the three shots already grouped so close together that it was wrecked. The projectile encountered so little resistance that it went on into the sand mound. Cracks from two inches to three inches extended from the centre through each shot hole to the edges. (*Figs. 26, 27, 28* and *29.*)

It is very clear from the above results the steel plate was very inferior, being little or no better than the compound plate tried at Annapolis in 1890.

The penetrations in the nickel-steel plate were eleven and one-half, thirteen and eleven inches for the six-inch projectiles, a slight crack being developed at the third shot.

Considering the disadvantages, as compared with the previous tests under which this plate was tried, it certainly made a very good defence, and probably if of the same dimensions and tested in the same manner, would have made as good showing as the similar Bethlehem plate.

The same peculiarities as regards the chipping of the metal about the points of impact, will be observed in these plates as in all the others treated by the Harvey process.

Methods of Hardening the Surface of Armor-plates.—Within the last few years two methods have been suggested for producing an intensely hard face upon steel, alloyed-steel or compound armor-plates. Several other schemes for producing a similar result have been proposed, but the only ones that have in any way been successful, are the Harvey, and the Tresidder processes. The former, an American, and the latter a British adaptation of two old and well-known devices for superficially hardening steel, viz: in the Harvey process, hardening by cementation, and in the Tresidder, by quenching with a spray or sprays of water.

The function and desirability of this extra hard face is sufficiently obvious when we consider the well-known fact when a projectile enters a certain distance into an armor-

plate, it receives great support from the surrounding mass of metal, so that any resistance offered to it when it has half buried itself is very much less effectual than if applied to the surface.

This simple fact accounts for the failure of compound armor composed of a hard steel plate sandwiched between soft iron and steel plates. It has been found that a projectile which was unable to penetrate a hard steel plate under ordinary circumstances would do so if a layer of wrought iron was added to the *front* of the steel face.

The aim of these two processes is precisely the same, but the means quite different. For the sake of brevity we may consider the change in the Harvey as chemical, and in the Tresidder as molecular, although as a matter of fact there is probably a combined chemical and molecular change in both cases.

Harvey Process.—This process was patented in 1888, improved and strengthened by subsequent patent in 1891.* It is described in the patent specifications as follows:

"The armor-plate having been formed of the desired size and shape from a comparatively low steel, such as Bessemer steel or open hearth steel, containing (say) ·10 to ·35 per cent. of carbon, is laid, preferably, flatwise upon a bed of finely powdered dry clay or sand deposited upon the bottom of a fire-brick cell or compartment erected within the heating chamber of a suitable furnace. The plate may be so embedded that its upper surface is in the same plane with the upper surface of those portions of the bed of clay or sand which adjoins the sides and ends of the plate, or the plate may, if desired, be allowed to project to a greater or less distance above the surface of the clay or sand. In either case the treating compartment is then partially filled up with granular carbonaceous material, which, having been rammed down upon the plate, is covered with a stratum of sand, upon which there is laid a covering of heavy fire-bricks. The furnace is then raised to an intense heat, which is kept up for such period of time as may be

* U. S. Patents 376,194, and 460,262.

required for the absorption by the metal adjoining the upper surface of the plate of (say) an additional one per cent. (more or less) of carbon; or, in other words, the quantity of carbon, in addition to that originally present, which may be necessary to enable the said metal to acquire the capacity of hardening to the desired degree. The temperature of the heating chamber outside of the treating compartment is brought up to a height equal to or above that required to melt cast iron, and is kept up for a greater or less length of time, according to the depth of the stratum which it is intended to charge with an excess of carbon. This period, however, will, of course, vary according to the efficiency of the furnace.

"The degrees of efficiency possessed by different furnaces can only be satisfactorily ascertained by actual trial. When ascertained, the reproduction of given results merely requires the re-establishment of the conditions as to time and temperature under which said results have been previously observed to be obtained. This involves merely the maintenance of the furnace at a heat sufficient to melt cast iron for the period which by previous observation has been ascertained to be the period required for adding to the tenacity of the steel and for the supercarburization of the plate to the prescribed extent and depth. For example, a plate (say) ten and one-half inches in thickness, composed of a comparatively low steel containing (say) ·35 per cent. of carbon, may be charged with additional quantities of carbon, gradually varying in amount from (say) one-tenth of one per cent. at a depth of three inches beneath the surface of the exposed side of the plate to one per cent. at the surface thereof by a continuance of the treatment for a period of (say) 120 hours after the furnace has been raised to the required temperature.

"The statement that the heat at which the furnace is maintained is sufficient to melt cast iron is to be regarded as approximate merely. The more intense the heat the better, and while it will, of course, be understood that the longer the treatment is continued the greater will be the depth to which the carbon penetrates beneath the surface

against which the carbonaceous material is packed, it is also to be remarked that the penetration of the carbon is greatly facilitated by the continuous firm compression of the carbonaceous material against the plate. As a general rule, the thicker the armor-plate the greater will be the permissible depth of supercarburization. A ten-and-one-half-inch plate and a depth of supercarburization of three inches are herein referred to merely for the purpose of illustration. After the conclusion of the carburizing treatment the plate is taken out of the furnace, and without removal of the carbonaceous material from its surface, is allowed to cool down to the proper temperature for chilling. During the cooling operation the carbonaceous material protects the hot supercarburized surface from the air, and thus prevents the formation of scale, which, if present, would interfere with the subsequent hardening of the metal beneath it. The carbonaceous material, however, may without injurious consequences be temporarily removed from and quickly replaced upon small portions of the supercarburized surface for the purpose of exposing them for observation. When it is seen that the supercarburized surface is so far cooled down as to have a dull cherry-red color, the carbonaceous material is quickly removed, and the plate is then chilled by being sprayed with torrents of cold fluid or by being submerged and kept in motion until cold in a large body of cooling fluid.

"*Fig. 30* is a transverse vertical section of the furnace, showing the armor-plate and the cell or compartment containing the bodies of material in which the armor-plate is inclosed. *Fig. 31* is a transverse section of a portion of an armor-plate shaded to symbolically represent variable degrees of supercarburization at different depths beneath the surface upon the side intended for exposure to the impact of projectiles. In *Fig. 30* the furnace A is represented as provided with a movable cover A', or it may be constructed with reference to having one or both of its end walls removed to facilitate the removal of the plate in a horizontal direction.

"Within the heating chamber A^2 of the furnace is the

treating cell or compartment *B*, which is preferably provided at the bottom with a series *b* of parallel rails, which are embedded in a stratum of sand *C* of the same height as the rails and are intended for the support of the armor-plate *D*. The space around the ends and sides of the armor-plate is also filled with sand *C'* nearly or quite to the top of the plate. A stratum of granular carbonaceous

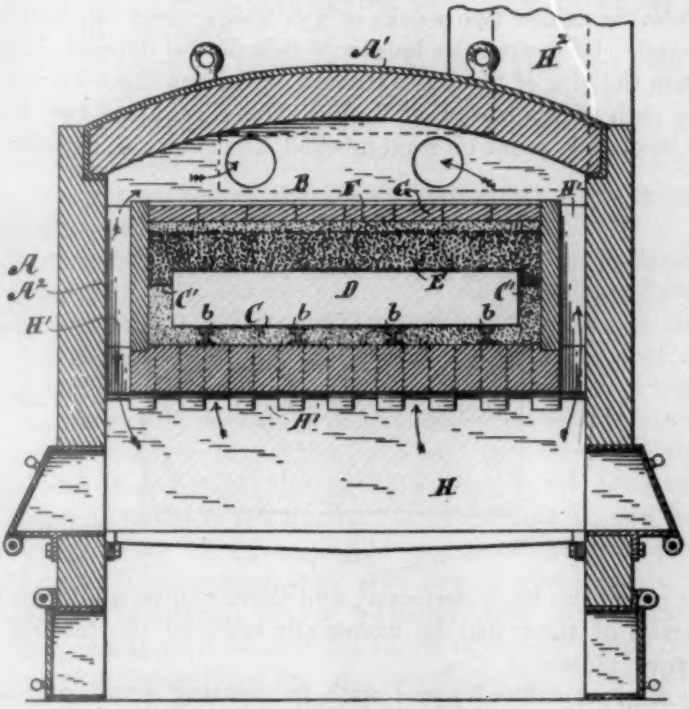


FIG. 30.

material *E*, rising to a height of (say) eight inches above the upper surface of the plate *D*, is tightly rammed down on to the top of the plate and is surmounted by a stratum of (say) two inches of sand *F*, covered by a layer *G* of heavy fire-brick. The stratum of sand *F* and the layer of fire-brick *G* not only protect the carbonaceous material from the fire, but also serve to weight the carbonaceous material down upon the plate."

The treating compartment *B* is heated by the flames and hot products of combustion from the fire chamber *H*, which are led upward through the flues *H* and directed inward over the tops of the treating compartment and finally discharged into the chimney or smoke stack H^2.

The carbonaceous material referred to is probably charcoal, although it is likely other substances have been tried. The length of time necessary to effect this carburization is probably nearer two weeks or 336 hours, than 120 hours as stated. Of course the length of this period depends largely upon the size of the plate treated; it seems the 8 x 6 feet by 10½ inch plates tested at Indian Head required two weeks or more. It must be remembered, however, the process has

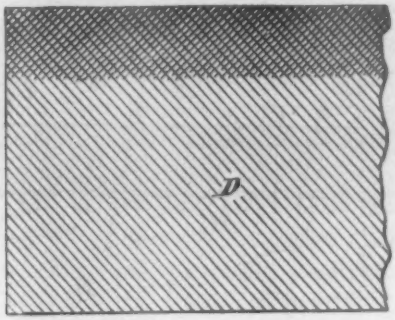


FIG. 31.

by no means been perfected, and there can be no doubt this period of time will be materially reduced in treating the larger plates.

A great difficulty met with in treating armor-plates by the Harvey method, is their tendency to warp or twist during the operation or in the subsequent quenching and tempering. This difficulty is not, however, peculiar to the Harvey treated plates and will be doubtless overcome as it has been in other cases.

Another objection urged against the Harvey method of treatment does not appear to be so serious. When iron or steel is subjected to the intense heat of the carburizing atmosphere of a cementing chest or furnace, certain chemi-

cal reactions appear to take place in the interior of the metallic mass by which gases and gaseous compounds are liberated.

Percy states,* these gases are probably due to the reduction of part of the protoxide of iron, with the evolution of carbonic oxide. While this might be true with wrought iron containing intermingled slag or cinder, it seems possible but to a very slight degree with steel produced by casting into an ingot.

It would seem out of place in a paper of this character to enter into a discussion of these most interesting chemical phenomena; we know from the researches of Müller and others† that steel under most all circumstances contains considerable quantities of the gases hydrogen, nitrogen and carbonic oxide.‡

Furthermore, we know that when steel is highly heated portions of these gases and gaseous compounds escape from the metal; it is therefore easy to imagine how the blisters may be formed by the gases rising to the surface of the metal but not quite breaking through its outer skin or layer.

The formation of these will obviously decrease the thickness and homogeneity of the hardened face of the armor-plate and if any depth below its surface must somewhat decrease its ballistic resistance. It is difficult to see how this obstacle can be overcome in the manufacture of the plate; even compressed steel will evolve some gas when heated. It is difficult to see, however, how these blisters can be considered a serious drawback to the efficiency of an armor-plate unless they are at a considerable depth below the surface, which is not often the case.

As we have already seen the Harvey process is essentially a cementing one, the additional hardness given by it to an armor-plate being produced by a superficial increase of its content of combined carbon. This increase does not extend far into the steel, as the amount of carbon thus added, appears to vary inversely with the depth.

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* *Iron and Steel*, p. 772.

† See Howe's *Metallurgy of Steel*, p. 105, *et al.*

‡ *Iron*, 1879, p. 649; also 1883, pp. 51, 244 and 245.

The following analyses give the varying amounts of carbon in two steel rails treated by the Harvey process. The idea is to make the top of the rail, which is exposed to wear, hard, whilst the balance of the rail remains soft and not subject to danger from breakage.*

Depth. Inches.	Amount of Carbon. *No. 1. Rail.*	*No. 2. Rail.*
$\frac{1}{16}$	0·76	0·76
$\frac{1}{8}$	0·42	0·42
$\frac{3}{16}$	0·33	0·31
$\frac{1}{4}$	0·30	0·30
$\frac{3}{8}$	0·30	0·30
$\frac{1}{2}$	0·33	0·30
$\frac{5}{8}$	0·30	0·27
$\frac{3}{4}$	0·30	0·28
1	0·27	0·26
$1\frac{1}{4}$	0·27	0·26
$1\frac{1}{2}$	0·27	0·25
Flange,	0·24	0·27

The hard face of the Harvey treated Bethlehem steel plate of the Indian Head trials of October 31, 1891, showed by analysis the following composition: †

	I.	*II.*
Combined carbon,	0·58	0·56
Graphitic carbon,	0·08	0·05
Phosphorus,	0·043	—
Manganese,	0·498	—
Silicon,	0·093	—
Sulphur,	0·019	—
Specific gravity,	7·845	—

While the Harvey process has in a measure accomplished the object for which it was designed, it seems to the author its present status cannot be considered satisfactory. It is at the best an exceedingly difficult and cumbersome operation to superficially cement and then to quench and temper such large masses of metal as ten and twelve-inch steel armor-plates. The time required to accomplish the object is great and the cost must be excessive, besides, the

* *Iron Age*, January 21, 1892, p. 118.

† The author is indebted to Mr. James S. de Benneville of Dr. Genth's laboratory for this analysis.

results obtained are uncertain and unreliable, as the plates may warp or blister to such an extent as to be worthless for defensive purposes. The process will undoubtedly be improved, for as the author has remarked before, many of the obstacles to its successful operation are mechanical. To the author's mind such cumbersome operations for hardening armor-plate seem essentially wrong; it seems to him the properties which produce the hardening effect should be inherent in the metal itself, and whether it be in the ingot or finished state these properties should remain latent until developed in quenching and tempering. Whether such properties exist in ordinary high-carbon steel or nickel-steel armor-plate and can be developed by such methods of quenching as the Tresidder process, remains to be seen. The Tresidder process certainly appears to have met with sufficient success to cause it to command our most careful consideration, although the description of its details, and the results obtained by its application so far made public are exceedingly limited.

Tresidder Process.—This improved system of quenching appears to be covered by the two British patents, 5,551, of 1891, and 22,177, of 1891, granted to T. J. Tressider, late Captain of H. M. Royal Engineers. It is stated in the specifications that the invention was suggested by the apparently unsatisfactory action of a water bath in hardening large masses of steel, due chiefly to the formation of a steam envelope round the immersed article, which envelope being continually broken and re-formed during the early stages of quenching, only allows the heat to be abstracted spasmodically instead of with the uniformity which is the first requisite for a successful result; that the superior action of an oil bath is due not to the chemical composition of the oil but to the absence of this steam envelope; and that the improvement in the action of a water bath due to the addition thereto of glycerine, or of any substance tending to raise the boiling point, is to be explained in the same way.

The object of the invention is to so apply water in quenching steel that the formation of a steam envelope

shall be impossible; but the invention is not limited to water alone, as any fluid or gas may be applied in the same manner.

It is claimed that the result of this method of quenching is to produce an intense superficial hardness in the surface of compound, steel or alloyed-steel plates, as well as increased tenacity and toughness, such as has hitherto been obtained by oil quenching and annealing.* The injurious and commonly fatal internal strains produced by ordinary water quenching are entirely avoided in this method.

The method of procedure is very fully stated by Capt. Tresidder in British patent 22,177, 1891, from which we quote at length:

"If the plate to be treated is a compound plate, I make it and machine it in the usual way except that I use false templates to which to bend it. These false templates are constructed from the designer's templates, as will be described further on. When the plate is finished as far as regards all machine work to the steel portion, all holes (if there be any, such as those tapped in the top edges of belt plates for the deck attachment), in the steel, are plugged with flush wrought-iron screw plugs arranged so as to be withdrawn with facility, similarly any keyways in the edges, if in the steel portion, are fitted with temporary keys. The plate is then carefully heated in a furnace to a 'hardening heat' which will, of course, vary with the nature of the steel; ordinarily a moderate red heat will suffice. When hot enough it is taken from the furnace and deposited steel side up on four supports in a large flat tray (*Fig. 32*) in such a way that the edge of the tray is everywhere a little higher than the bottom of the plate. An apparatus, which I call a douche, consisting of a system of pipes, perforated with a large number of small holes, in connection with water supply (*Figs. 32* and *33*) is then brought up and supported a little above the plate, and the water is turned on. At first the water quenches the steel side only, but in a few

* Although it is not stated in the patent specification, high-carbon steel or nickel-steel is presumably included.

moments the tray becomes full and forms a bath to the lower iron side. The object of this is to reduce the warping of the plate, which it does by about one-half; it also tends to assist the chilling action of the douche above, but the soft iron on which it acts is not affected.* If the utmost

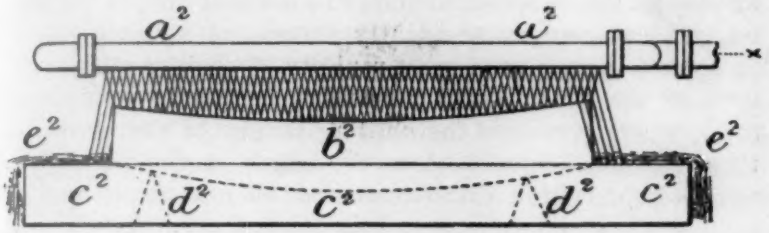

FIG. 32.

possible degree of hardness is desired the douching is continued till the plate is cold, but I sometimes stop the water after all redness has disappeared, throw on the plate some scraps of soft alloy, and turn on the water again as soon as these scraps show signs of melting. In this way, by using

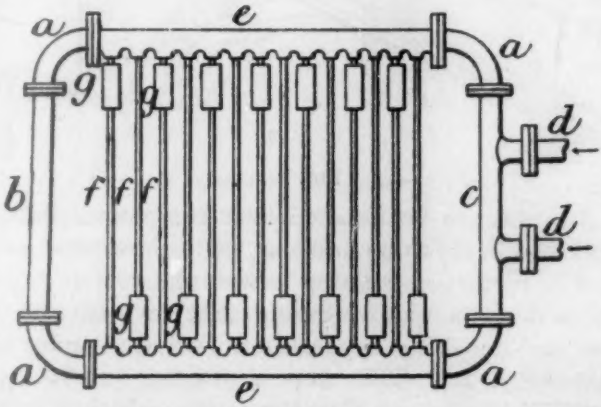

FIG. 33.

alloys of suitable melting points, the plate can be tempered with great nicety to any required degree. When the plate is cold it will be found to have its proper finished shape if

* This description applies to compound plates, but as we have stated the invention is not confined to this type of plate. F. L. G.

the false templates have been correctly made and worked to. The temporary plugs and keys (if any) can then be withdrawn and the bolt holes drilled and tapped in the back to complete the plate. No correction whatever of the edges should be required, but if a little proves necessary I employ an emery wheel mounted in the tool box of a planing machine, and independently driven, as a planing tool. In order to prevent too great rapidity of cooling at the corners of the plate I sometimes attach thereto iron shoes (*Fig. 34*) which modify the chilling action of the water at those parts. In special cases the edges of the plate also may be protected in a similar manner even to the extent of keeping them soft enough to be machined (*Fig. 34*).

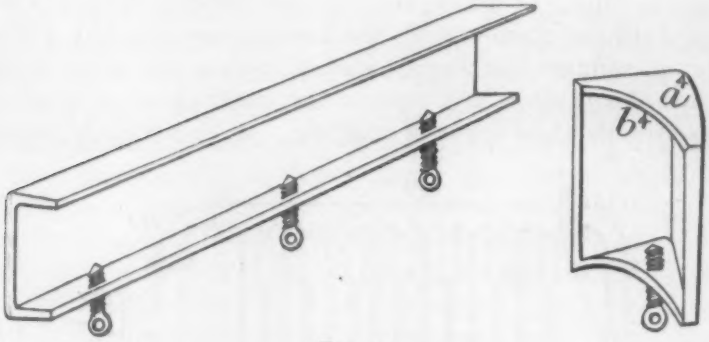

FIG. 34.

"If the plate to be finished is a compound plate (steel face and iron back) to be finished with considerable curvature (as a turret or conning tower plate, etc.), I proceed exactly as described above except that instead of a tray I use a second douching apparatus to cool the under side of the plate (*Fig. 35*). This acts upwards, but it must be remembered in all cases that the douche which is to harden the plate is at its best advantage when acting directly downwards.

"If the plate to be treated is a compound steel plate in which the back is of so mild a nature as to undergo water quenching without losing toughness, the double douche as described for a curved compound plate may be used; but if

it is undesirable to quench the back then the downward douche on the face only, without any tray to hold the water up against the back, is to be preferred. In this last case the false templates will require to be differently designed, as described further on. Another method is to use the double douche with water above the plate, and air or wet air below."

(4) If the plate to be treated is a homogeneous steel plate requiring toughness throughout rather than a hard face, either the double douche or the single douche with tray will be efficient, and false templates are not very important in such a case since the plate can be "set" after treatment without heating. But in a case of this kind I prefer to use a double douche of a wet air applied in the same way as

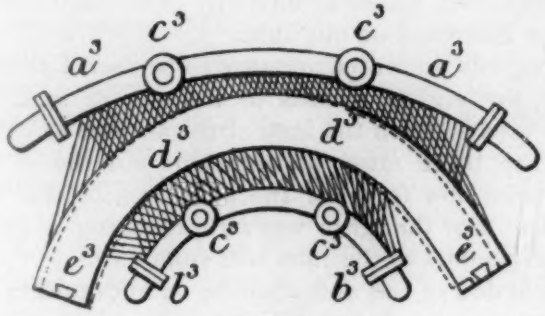

FIG. 35.

the water. The air is wetted by passing through a chamber into which tiny jets of water are allowed to play or by the method, described in my patent 12,347 of 1887, and it then passes into a box one side of which is full of perforations or into the same douche as described for use with water or other fluid.

"Repeated experiments have shown that the warping produced by quenching a straight plate nine or ten inches thick from one side only is of a uniform convexity towards the quenched side, and that the amount of convexity is about three-eighths inch in a distance of four feet; also that the warping of a steel-faced compound plate of the same thickness quenched from both sides is similar in nature, but less in extent being at the rate of about one-fourth inch in

distance of four feet. Homogeneous steel plates equally quenched from both sides after being uniformly heated have no tendency to warp. Experiment has also shown that by bending a flat plate till it is concave on the side to be hardened to an extent determined in the manner above specified, its flatness will be restored by the warp due to quenching. Thus plates to be treated by this process must be originally bent with less convexity on the hard side than ultimately required, and the proper form for the false templates previously alluded to can be arrived at approximately by applying one of the corrections given above and with accuracy after a few trials with the particular kind of plate to be treated. Thin plates warp more than thick ones. A plate four inches thick shows a convexity of one-half inch in four feet when hardened on one side.

"As regards the water pressure to be used I prefer a high pressure, say eighty pounds to the square inch, but this depends greatly upon the area of the surface to be treated; in any case there must be sufficient volume of water to cause a brisk flow from all the apertures of the douching apparatus. For the air or wet air quenching a pressure of about ten pounds to the inch will suffice.

"The action of the water douche on high carbon steels is, as might be expected, to produce intense hardness. As the carbon is lower, the hardening becomes less marked, but an appreciable hardening or stiffening effect is produced with steels containing as little as two-tenths of one per cent. of carbon. In such a case the effect of the treatment resembles that obtained by hardening a steel of somewhat higher carbon in oil at about 1,500° F., and then annealing at about 900° F. The wet air has a milder action (on large masses) about that of oil hardening at 1,300° F., and annealing at 1,200° F. Dry air, especially hot dry air, has the mildest effect of all, but the uniform distribution of the cooling action peculiar to this invention always results in improving the steel."

It seems rather odd that the application of this kind of device to armor-plate should be patented at this late day. A number of years ago Jarolimek mentions the difficulty of hardening steel in water, owing to the formation of a film of

steam on the surface of the heated metal, and suggests the use of jets and sprays as obviating to a great degree the difficulty.*

He particularly recommends a fine spray of water produced by means of an air blast, and states "this apparatus affords a mixture of air and fine particles of water, which strike with great velocity against the hot steel, the result is not only a rapid conversion into steam, but the steam formed is quickly carried away, so that it is possible to obtain extraordinary hardness and, what is more important, a uniform hardness in the steel."†

The degree of hardness obtained will, of course, depend greatly upon the amount of carbon present, the lower the carbon the more rapid and violent the cooling must be to produce the hardest effect possible. Pure cold water is undoubtedly the best substance for producing the hardness so essential to armor-plate. When applied in the manner described by Capt. Tresidder, its maximum efficiency in rapid cooling is probably reached, besides, in order to produce a uniformity of hardness it is essential that the quenching should be coincident over the entire surface of an armor-plate. These requirements the Tresidder method appears to meet, and it seems likely it will give good account of itself in the near future.

The results of the only important trials of Tresidder treated plates which have been made public are those of the *Nettle* trials at Portsmouth, October 2, 1891. Some experimental plates were tried at Shoeburyness during the summer of 1891, but the results obtained were not as important as the more recent ones.‡

The Tresidder treated plate tested at Portsmouth was made by Brown & Co., of Sheffield, on the Ellis system of making compound plates. It was of the usual dimensions,

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* The efficiency of a water spray or douche in hardening tools is well known. F. L. G.

† *Metallurgical Review*, No. 1, 1877–1878, pp. 157, 158.

‡ *Engineer*, November 6, 1891, p. 374. *Engineering*, November 6, 1891, p. 543.

8 x 6 feet by 10½ inches, and weighed 9·4 tons. The conditions of the trial were as follows: Gun B. L., six-inch; powder, 48 pounds; projectile, 100 pounds; range, 30 feet; striking velocity, 1,950 f. s.; striking energy, 2,637 f. t.; energy of each blow, 288 f. t. per ton of plate. Rounds 1, 2 and 5 Holtzer a. p. projectiles; rounds 3 and 4 Palliser chilled iron projectiles—no eight-inch projectiles were used.

It will thus be noted while many of the conditions are similar, the test was much less severe than those of the

FIG. 36.

Annapolis and Indian Head trials, where all the six-inch projectiles were Holtzer steel, and in all cases an eight-inch projectile was fired into the centre of each plate.

Round 1, at lower right-hand corner, projectile broke up, bulge on back 0·4 inch; two cracks developed (*Figs. 36* and *37*.) Round 2, upper left-hand corner, projectile broke up; bulge on back 0·9 inch, several cracks developed. Round 3 (Palliser), upper right-hand corner, projectile broken up; bulge at back 0·6 inch. Round 4 (Palliser), lower left-hand corner, projectile broken up; bulge at back

0·3 inch. Round 5, centre, projectile broken up; bulge at back one inch, numerous cracks developed.* (*Figs. 36* and *37*.)

A rather marked peculiarity observed in some of the plates at the Indian Head trials was the apparent difference in the resisting power at the several points of impact on the same plate. Thus in the Carnegie low-carbon nickel-steel plate (*Figs. 10, 11* and *14*) the penetrations of the

FIG. 37.

upper two six-inch projectiles was 26·5 and 26·3 inches whilst the lower two were only 14·6 and 13·1 inches. A similar peculiarity was observed in the Harvey high-carbon nickel-steel Bethlehem plate; in this case the penetrations on the right-hand side of the plate were 6·8 and 7·3 inches, on the left twelve and twelve and one-quarter inches, showing one side to have about half the resistance of the other. It will be noticed from *Plate II* and the preceding table, the

* *Engineer*, November 13, 1891, p. 397. *Engineering*, November 13, 1891, p. 571.

penetration of the third shot on the Harvey low-carbon steel Bethlehem plate was 26·96 inches, being about two and one-half times greater than the other six-inch projectiles penetrations on the same plate. Again, in the case of the Harvey low-carbon nickel-steel Carnegie plate the fourth six-inch projectile penetrated 20·5 inches or about one-fourth more than the other six-inch projectiles on the same plate. (See *Figs. 17, 18* and *22.*)

A somewhat similar irregularity was observed in the previously mentioned Brown compound plate treated by the Tresidder process. (See *ante*, and *Figs. 36* and *37*). The lower part of this plate appearing to be considerably harder than the upper.

It is likely the irregularities in the last two Harvey treated plates are due, in part at least, to a want of uniformity in the supercarbonized or hardened face.

In the two previous cases, however, this cause could hardly account for the great and what one might term a regular irregularity or difference in ballistic resistance.

It has been unofficially stated that this regular difference in resistance at the two sides or ends of the same plate was due to the manner of quenching; that the plates were lowered into the oil bath sideways or endways, as the case may be, and as a consequence but a small portion of the oil could come in contact with the heated metal at the same instant. The oil thus becoming locally or highly heated it could not produce the same chilling effect on all parts of the plate.

This difficulty is readily overcome, however, by lowering the plate into the oil or water-bath, as the case may be, face downwards so that the chilling effect takes place practically at the same moment over its entire surface.

The author understands this was done in the case of several of the plates at the Indian Head trials. The penetrations in both of the high-carbon nickel-steel plates were certainly comparatively uniform.

Under ordinary circumstances the degree of hardness, imparted by quenching is dependent upon three conditions, viz: the amount of carbon present in the steel; the differ-

ence of temperature between the heated metal and the fluid employed, or the rapidity with which the cooling takes place.

The problem now before steel armor-plate makers is to produce the greatest degree of hardness and elasticity with the least amount of carbon, because the greater the amount of carbon in the steel the more difficult it is to work.

Cumbersome methods for increasing the content of carbon and consequently the hardness, are not desirable. It seems safe to assume that the maximum hardening effort of the carbon usually present in the steel is seldon or never developed by the common methods of quenching armor-plate. Large masses of steel can never be hardened to the same degree as a small tool, for instance, by a simple immersion into a cooling fluid. Apparently the lower the carbon the more rapid and violent the cooling should be to yield a maximum of strength and hardness.

The elasticity of the steel is to a certain degree regulated by the difference of temperature between the heated metal and the fluid employed. This difference should be great if harder steel with less elasticity is desired—and conversely.

These conditions can be modified by using a warm liquid for cooling, or one of high conductivity without changing the temperature of heating.

Oil quenching usually gives a higher tensile strength and elongation than water quenching. Oil or water quenching is sometimes apt to produce splits and cracks, and for that reason molten lead has been largely used in France.

With lead quenching the chilling effect is of course slight, but the cooling is very slow and regular, which for some reasons is very desirable. Some very hard steels can be quenched in lead which could not be treated successfully in any other manner.

The Société Chatillon et Commentry claim that their armor-plate tempered (quenched) by their lead bath system shows much greater resistance than the plates treated by the ordinary methods.*

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* *Le Genie Civil*, vol. xiii, pp. 22–24.

The claims made for this system of lead quenching are undoubtedly extravagant; such a slow and gradual cooling cannot harden the steel, but it will probably increase the elastic limit and elongation and possibly the tensile strength. The increase of these factors will, of course, tend to increase the ballistic resistance to a limited extent. A very hard face cannot be developed by this or any other system of quenching by immersion if steels or nickel-steels of the average composition (say 0·40 per cent. carbon and three per cent. nickel) are used.

The entire subject of quenching and tempering steels is a most troublesome one, and one, moreover, about which there is much to be learned. It is not particularly difficult to obtain a desired temper with small masses of steel, such as tools, etc., but in dealing with such large masses as armor-plate in which internal strains are easily set up, the problem becomes a most difficult one.

The thickness of armor cannot be increased beyond its present proportions unless the specific gravity of the material used be much less than that of steel. The improvements made in armor to meet the increasing power of the gun must, therefore, be in the line of hardness and elasticity; how this is to be accomplished, it remains for the metallurgist to determine.

THE CONSTRUCTION AND INTERIOR ARRANGEMENT OF BUILDINGS DESIGNED TO BE USED AS THEATRES.

BY C. JOHN HEXAMER.

[*Read at the stated meeting of the Institute, held Wednesday, May 18, 1892.*]

Ten years ago I read a communication before the Institute "On the Prevention of Fires in Theatres," which was generally applicable to the theatres of our country. I have been called upon by your Committee on Meetings to say a few words on the same subject to-night, but more specifically in regard to local conditions. My remarks of ten years ago appeared in the *Journal*, and the matter seemed of such importance to the Institute that a special committee, with myself as chairman, was appointed to investigate and suggest better features in our American theatres.

Although not as much good as we had anticipated resulted from our labors (embodied in a printed report), we at least had the satisfaction of knowing that many of our suggestions were adopted in the rating schedules of underwriters; some, which had been decried as impractical by stage carpenters, have been introduced, and are now regularly in use in a number of places of amusement. It is difficult to achieve progress of any kind where a decided material return is not in view for the money expended.

Allow me to rapidly make a few suggestions which are no longer novel, recapitulating much that I have said on former occasions, before proceeding to what is new and of local importance.

A theatre should consist of four separate and distinct buildings, like the Park Theatre, separated by substantial brick walls, rising above the roofs, all communication to be cut off by the best known fire-resisting means. [The Park Theatre is, however, not a fire-proof structure, although in its general plan the most rationally designed of all our Philadelphia play-houses, and should it at any time burn

down, do not accuse me of the statement that it was fire-proof!]

(1) There should be a fire-proof auditorium (as fire-proof office buildings are now constructed).

(2) A stage building.

(3) A fire-proof building for dressing-rooms, etc.

(4) A fire-proof storage room for scenery, properties, etc., with fire-proof doors.

The proscenium wall should rise well above the roofs of all the buildings, with an iron girder covered by a good non-conductor, relieved by an arch, the weight of the wall above being sustained by the arch, so that if the girder gives way, by exposure to the intense heat of a fire, the wall will remain in place. Designers and managers usually prefer to close off the stage opening, square at the top. Where this is not desired the girder should be dispensed with. The wall should cut the stage-floor with incombustible material. When several years ago the Academy of Music was improved I again made this suggestion (this had previously been decried as an absurdity and practical impossibility) which was carried out, and has been in use since without annoyance or inconvenience of any kind. The wooden stage floor was cut, the wall being "brought up" near the level of the stage floor, and was finished off on the top with a heavy coat of cement which, when dry, corresponded in color with the wooden floor, and is not noticeable from the auditorium. Instead of being disagreeable to dancers, I was informed by the late Mr. Higbee, that the "*premieres*," selected the smooth, hard cement pavement for their "*tour de force*." It is self-evident that where the wooden stage floor is unbroken by an incombustible barrier, fires will be transmitted *beneath the fire curtain* from the stage to the auditorium.

The curtain should be of real asbestos, not half cotton, with an interior network of strong, woven, pliable wire to give it tensile strength, and should slide in iron grooves, at least six inches deep on both sides of the stage, securely bolted into the masonry of the proscenium wall.

All of the four buildings should be provided with large,

separate exits to the open air. Every part of the auditorium should have separate exits, and the exit of one part should never be allowed to discharge into that of another.

All corridors should increase in width from the theatre to the open air.

All extra exits (fire corridors) should be marked as such in large, bold letters; should be lighted by oil lamps (not petroleum products; sperm or lard oil is recommended), and should be unbarred from the opening of the theatre until it is closed. Before the close of every performance, they should be opened, so that the extra exits may become known to the public.

All doors should open outwards (a precaution which is still neglected in some of our concert club halls).

Long rows of seats should not be permitted. Rows should be cut by aisles at short intervals.

Movable seats should not be allowed. Seats should be tightly screwed to the floor. Fixed chairs with a spring attachment, which throws back the seats when not occupied, are strongly recommended.

No scenery, properties, materials or impediments of any description should be allowed to remain in the corridors.

The fire-proof drop-curtain should be kept down at all times except during rehearsals and performances; after which it should be immediately let down, and not raised until a few minutes before the beginning of the next performance. The lowering apparatus should be so arranged that the curtain will be lowered automatically in case of fire.

Doors in fire walls should have stone sills, and should be tin-lined on both sides, constructed according to the underwriters' specifications, without springs or locks, so they can readily be opened.

Incandescent electric lights should be used throughout, and all others should be prohibited on the stage.

The system of lighting the stage should be separated from that of lighting the auditorium; each should have a distinct circuit. The system should be installed under the

direction of the electric light inspector of the Fire Underwriters' Association. An ordinance should prohibit theuse of lights until so approved, and the certificate of approval has been issued, and a fine of $1,000 for each offence should be imposed. Should managers be satisfied in placing electric lights like gas lights, and leaving them in place as they usually do the latter, there would be little danger from incandescent lights which have been inspected and passed; but electric lights are so easily moved, and the novel scenic effects which can be contrived with them are so tempting, that these are frequently rearranged and this practice becomes exceedingly dangerous when carried on by ignorant persons, therefore expert supervision is most necessary.

It seems clearly established that the recent Central Theatre fire was caused by a gas light, which would have been impossible had electric incandescent lights been used exclusively. It may not be uninteresting to quote here what we advocated ten years ago:

"The greatest number of fires are caused by the paraphernalia of illumination. The danger of coal oil, which is much used in our country and Western theatres as an illuminating agent, is self-evident, but the hazards of gas, which until within a few years was the safest material at ou command, are not so well understood. Besides the dangers of leakage and explosions, we have, in the case of illumination, hundreds of *flames* spread throughout a building, each forming a dangerous sphere around itself. Although the last-named dangers can and should be lessened by proper precautions, such as wire baskets and shields over the flames, still, when we consider the close proximity of the border lights to combustible gauzes and canvas, and ponder on the hazards of temporary illuminating effects, where jets are fed through rubber hose which must be removed during change of scene, we must ask is there no other method of illuminating by which equally good artistic effects may be produced, and which at the same time will lessen or entirely do away with the hazards of the present system? Fortunately means are now at hand. By the labor of eminent electricians, we have at our disposal an agent by which the

same, if not more brilliant, effects than with gas can be produced, while doing away with the dangers of gas, the lamps themselves being absolutely safe," etc.

Where electricity is generated in the theatre, the boilers, engine and dynamo should not be located in the stage building, and lights in stairways should receive their currents from outside independent sources.

A large reservoir, the bottom at least ten feet above the highest sprinkler, holding at least 5,000 gallons should be introduced. It should always be kept full of water, connecting with the standpipes and not allowed to freeze. (This can easily be accomplished by passing the exhaust steam pipe through it.)

Every theatre should be supplied with a sufficient number of fire hydrants, connected with the tank, with hose and nozzle attached ready for instant use and not removable. The tank connection is important as the city water pressure is so feeble in some districts (having been found by actual tests to be as low as twenty and twenty-six pounds), that it would be impossible to squirt to the top of the stage, with the appliances now in use in some play-houses.

The stage and workshops, and if there is an attic above the auditorium, this also, should be fully equipped with an approved system of automatic sprinklers, connected with two supplies, an approved pump and tank, both of which should be located outside of the stage building. Automatic apparatus is worthless unless in perfect working order, and should, therefore, frequently be carefully inspected, tested and reported upon. The following underwriters' report on the sprinkler system of one of our theatres will give you an idea how this should be done; also of the *necessity* of laws, official municipal inspections, and fines for neglect in these matters. [I withhold the name of the theatre.]

System; Wet Pipe; Equipment.—Full protection under roof, gridiron, fly galleries and stage.

Water Supply.—4,000 gallon tank on roof. Bottom of tank is elevated ten feet above highest sprinklers. Tank is filled by steam pump and has steam pipe inside.

Condition of Equipment.—Fair. Rising main is three inch.

Pipe sizes are correct. Check valve at tank to operate automatic alarm, which is located on stage and in good order. Pet cocks in upper part of system. No city water or pump connections for supply. No hose attached to sprinkler system. Draw-off pipe approved.

Remarks.—The water in tank has been *repeatedly* found *low and frozen*, and *it is evident that proper attention is not given to the sprinkler system.* We therefore rescind the sprinkler allowance until further notice.

A sufficient number of fire buckets (used in case of fire only), kept always filled, should be distributed conspicuously over the premises.

Each theatre should have at least two firemen (one on each side of the stage).

Every play-house should be connected with the nearest fire station by electric alarms in the office and on the stage, the latter to be further thoroughly equipped with automatic alarms.

Theatres should be patrolled at day and night by watchmen, who should be controlled by electric watch-clocks, with stations distributed over various parts of the buildings, records to be kept on file for the examination of the inspector.

No smoking should be allowed in the theatre, except where required on the stage in the representation of plays.

Steam or hot water should be exclusively employed for heating.

Scenery and other stage supplies should not be stored on the stage, but in a separate fire-proof dock.

No more scenery should be put upon the stage than is necessary for, at most, two performances.

The use of fireworks, roman candles, red fires, etc., should only be permitted when it has been shown to the Theatre Inspectors' satisfaction that the scenery and gauzes have been impregnated by proper substances, and that the woodwork has been covered by some satisfactory solution.

Wads of pistols and guns should be of hair only—not paper or cotton.

If straw, hay or any other easily inflammable substance be required in a scene, it should be impregnated and

be removed to a fire-proof place immediately after the scene in which it is used.

So much interest was manifested in an exhibition of some "*fire-proofed*" (impregnated) substances and the results seemed to be so novel to many of those present that, perhaps, a few additional remarks may not be amiss. Ten years ago I wrote:

"The experiment of making certain pieces of decoration of an incombustible material has been tried many times, and with considerable success. Especially the flies, as being most exposed and hanging among the border-lights, have in some cases been made of fine wire gauze. The interstices were then filled with an incombustible substance, and the flies were then painted in the usual manner. This method certainly gives entire security against fire, and the greater amount of first cost is more than counter-balanced by their greater durability; but the inconvenience of handling such pieces is greatly increased by their greater weight, making them practically impossible for drops, and larger wings and flats."

Another device is to protect the wood and canvas by painting it with suitable materials, and thus to make it incombustible.

After the rebuilding of the Opera House at Munich (destroyed by fire, 1823), the wood-work was given a few coats of water-glass. This kept well for twenty years, but later trial showed that the coating of water-glass had changed its *chemical composition, and gave no further security.*

Water-glass is further objectionable on account of the gloss it imparts to scenery, thereby reflecting light, and spoiling the artistic effect of the painting.

The impregnation of scenery before painting has been strongly advocated, and especially of the aforementioned flies. Some of the different substances used for this purpose are alum, sodium sulphate, borax, the soluble fluorides, and calcium sulphate. It was claimed that by impregnation canvas became so far incombustible that it could neither propagate flames nor glow for any length of time, and even under great heat would only char.

After the fire at the Berlin Opera House the authorities ordered the soaking of all scenery in a solution of alum.

The same question was raised and given to a commission to decide some twenty-five years ago in Paris. On account of the report of this commission an ordinance was issued enforcing the impregnation of all scenery. This was carried into effect in several theatres until, unexpectedly, some impregnated gauze was set on fire by the heat of a candle. The mayor had the case investigated. It was found that the ingredients used had lost their protective power, and had changed the chemical composition of the paint.

The writer ascribes the failure of these experiments to the manner in which the process was conducted; the canvas being in all cases merely soaked in the solution and then dried and painted. If a piece of canvas is soaked in water-glass and allowed to dry, the liquid in losing its water will contract more and more, until finally the solid particles will sit loosely on the *yarn* of the canvas.

Again, sodium tetra-silicate (water-glass being soluble in water), is dissolved on coming in contact with water. The water-colors used in scene painting may therefore have dissolved the greater part of the silicate at the start.

To obviate this the author would suggest the following: After thoroughly soaking the canvas in water-glass it should be placed in a dilute solution of hydrochloric acid; this would precipitate the silica inside of the *fibres* of the yarn itself. The reaction being the formation of silica, sodium chloride and water; viz: $Na_2Si_4O_9 + HCl = 4SiO_2 + 2NaCl + H_2O$. The silica, being insoluble in water, could not be washed out, and, on account of its precipitation in the fibres, could not readily be thrown out, this process being a parallel case to the use of a mordant in dyeing; the linen in that case being first soaked in color, and this then precipitated (made fast) by the mordant. As silica has no gloss, this process would also get over that difficulty.

Of course, any other incombustible substance precipitated into the fibres will answer as well as the above.

Other solutions recently recommended for purposes of

impregnation are: Versmann's and Oppenheim's, who advise a solution of 2 parts of sodium tungstate with 3 parts of sodium phosphate; Nicoll, one consisting of 6 parts of alum, 2 parts borax, and 1 part dextrine dissolved in soap-water; Siebdrath uses 5 parts of alum, 5 of ammonium phosphate, and 100 parts water; Patera, 15 parts borax, 11¼ parts of sodium sulphate, and 100 of water; Martin (see later invention further on), 8 parts ammonium sulphate, 2½ of sodium carbonate, 3 parts boracic acid, 2 of borax, 2 of starch and 100 of water. And very recently it has been suggested to use a solution of magnesium chloride.

The combustibility of scenery is also greatly lessened by painting it on both sides, as the fuzz on the back of scenery, along which flames spread, is thereby destroyed, etc.

Scenery might be made much safer than it is by simply whitewashing the back of it, thus destroying the fuzz. This is an exceedingly cheap and simple operation, and there can be no excuse for not carrying it out, etc.

And in the later committee's report:

"The only manner in which the dangers of fireworks may be lessened is by "*impregnating*" all scenery and gauze by approved processes. Your committee has for the past six months experimented with all ascertainable processes of impregnation. A process which your committee has found to be deserving of entire public confidence is that of Dr. J. Pafen, of Frankfort, Germany.

"Satisfactory results have also been obtained by the processes of Gautsch and Judlin, by sulphate of ammonia, and by silica deposited in the fibres by precipitation.

Besides impregnating the scenery, the woodwork should be covered with some fire-proof paint. Your committee experimented with a large number of solutions, and had most satisfactory results from real 'asbestos paint,' and especially from the so-called asbestos concrete."

I will now add that the following processes are patented in the United States:

(1) Zapfle, No. 199,950, February 5, 1878.
(2) Mathes, No. 254,560, March 7, 1882.
(3) Bartlett, No. 300,190, June 10, 1884.

(4) Fröhlich, No. 310,404, January 6, 1885.
(5) Smith, No. 314,886, March 31, 1885.
(6) Konrad, No. 319,100, June 2, 1885.
(7) Martin, No. 331,312, December 1, 1885.
(8) Sornberger, No. 362,232, May 3, 1888.
(9) { McIntyre, No. 391,327, October 16, 1888.
{ McIntyre, No. 391,261, October 16, 1888.

The compositions of which are roughly as follows: (Those specially interested can readily look up more thoroughly the specifications in the institute library.)

(*1*) *Zapfle*—Hydrochloric acid (purified by chloride of barium), carbonate of lime, crystallized alum (with potassa base), chlorate of ammonia, borax and water.

(*2*) *Mathes*—2 parts soda, 1 part alum, ¾ part borax, ¼ part potash, 6 parts water-glass, and water.

(*3*) *Bartlett*—200 gallons water, 400 pounds sodic chloride, 200 pounds ammonium chloride, and a solution of 156 pounds carbonate of potash and hydrochloric acid, neutralized by 75 pounds of bicarbonate of soda.

(4) *Fröhlich*—Compound of silicate of soda, alum, sodium chloride and phosphate of ammonia.

(5) *Smith*—Sulphite or hyposulphite of soda with muriate of ammonia; common rock salt is added for incrustation.

(6) *Konrad*—Solution of sulphate of ammonia, carbonate of ammonia, borax, bichloride of mercury, peppermint, carbolic acid, bitungstate of soda, and chloride of lime, transformed into an emulsion by leading into the solution the products obtained from the distillation of a solution of Peruvian balsam and camphor in acetic ether.

(7) *Martin*—(Specimens of inflammable substances treated by this process were shown and tested at the meeting.) Glycerine, ammoniacal salts and fire-resisting and preservative substances. Specified as 2 parts by weight of glycerine, 1 carbonate of ammonia, 8 hydrochlorate of ammonia, ·8 soluble cream tartar, ·8 oxalate of potash, 8 boracic acid and water.

(8) *Sornberger*—1 gallon water, 1½ pounds chloride of

sodium, 1½ pounds chloride of ammonium, 10 to 30 grains potassium permanganate, 4 ounces sodic sulphate.

(9) *McIntyre*—Ammoniacal and preservative salts and sulpho-ricinoleate of ammonia.

I have had occasion to test the latter with good results. It is claimed that the sulpho-ricinoleate prevents the dropping out of the salts: which in case of the Martin process is accomplished by means of glycerine.

The trouble with most solutions has been that when the salts have, in the course of time, become thoroughly dried they drop out of the fibres; this can be prevented by using a hygroscopic substance in the compound, as glycerine in the Martin process, which, although in minute quantities, continues to absorb moisture from the atmosphere, thus preventing the absolute drying and disintegration of the salts. I can see no reason why other hygroscopic substances, such as calcium chloride, zinc chloride, etc., will not serve the same purposes as glycerine in such compounds.

Laws making the treatment of scenery in new theatres compulsory (as in New York), have not been successful. Although the "*stock*" scenery of a new theatre must be impregnated before the play-house is allowed to be opened; the travelling companies, with each piece, bring in materials which have not been treated, and which may cause a fire. The only remedy would be stringent laws and heavy fines against the *use* of *any* untreated materials.

A large smoke flue should be provided above the stage. Automatic devices are recommended. These and the reasons for their introduction I described in a former paper.

That the public itself may have control in this matter, a complaint book should be laid open to the public in every theatre, where any individual may enter faults of construction or arrangement which he has noticed. This book should not be the property of the proprietor of the theatre, but should belong to the Theatre Inspector, the Fire Marshal and Building Inspectors.

The workshops and paint loft should be outside of the stage building.

Ground plans of the auditorium, giving a clear idea of

the building, corridors, stairways, etc., should be prominently located in the halls, and should be printed on the back of programmes.

We all know by experience that any matter which devolves on a number of persons, especially when their time is fully occupied by other duties, is done badly, or not at all. As the old adage has it, "Everybody's business is nobody's business;" therefore, in order to keep control of the various theatres, a theatre inspector should be appointed, who should have full power to enter a theatre at any moment, and whose duty it should be to see that these or other suggestions, made law by ordinance of Councils or an act of Legislature, are faithfully carried out, to inspect watchmen's records, etc., test fire appliances, and once a month make a report on each theatre.

These reports should be kept on file by the Director of Public Safety, and can be used as evidence against managers, or against the inspector, should he become derelict in his duties.

I quote an Underwriters' Association report, in order to give a general idea how such reports should be made. (I purposely do not give the name of the theatre, which, since this inspection, has been somewhat improved.)

Date. . . . . .

Report No. . . . . .

Location. . . . . .

Building and Fixtures.—Walls brick; roof tin and slate, mansard in rear; cornice wood, boxed; walls coped 5 feet lower than building adjoining on east; 12 inches between front communicating building and theatre on south; skylights thick glass, no screws; columns iron in galleries; galleries two; ceilings plastered; communication to front building, occupied by merchant tailor, gas burner company and offices and lobby of theatre; fire shutters and doors none; heating by furnaces well arranged; lighting, city gas, each section separated and controlled at gas table on stage; gas lighted by electric spark; border, foot lights etc., caged; proscenium, arch, frame; electric arc lighting in lobby and in front on street.

Fire Protection.—The fire protection consists of a three-inch stand pipe supplied by city main, with only one outlet which is in property room at rear of stage, 75 feet of good linen rubber lined 2½ inch hose attached to stand pipe by globe valve and Jones coupling; one cask for water each side on stage and one in flies on the prompt side; six metal fire buckets each side on stage and two each side in flies; running water on O. P. side of bridge; no buckets in auditorium; watchman nights and Sundays, no clocks; city water 27½ pounds pressure at 3 P. M.; smoking allowed only as the business of the play demands.

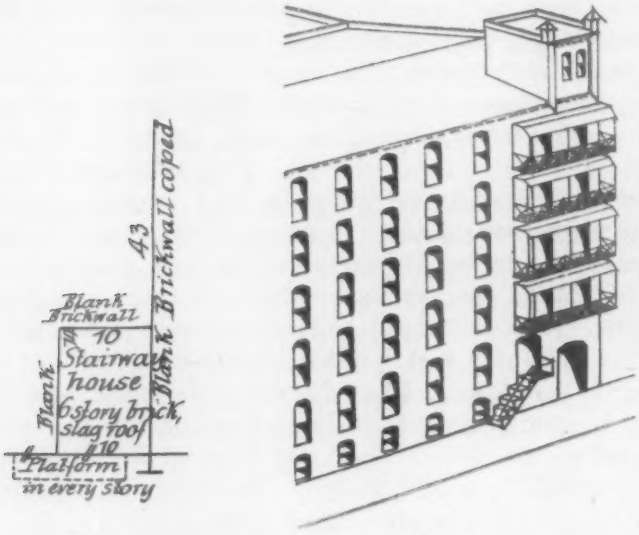
General Information.—No boiler; ashes loose; waste paper, sweepings and rubbish allowed to accumulate under stage; carpenter work done on stage; glue heated by gas on bridge safe; water colors only used for scene painting; scenery stored on stage: property and dressing rooms in rear of stage, separated by frame partition; water casks and fire buckets very much neglected; in one instance water cask had fallen apart for want of proper care.

The theatre building is in direct communication and one and the same risk with building where the merchant tailor tenant is using a gasoline pressure stove for generating steam in sponging cloth, carrying from one to five gallons of gasoline on second floor; the theatre building proper was originally an old stable. Building in fair repair; order and cleanliness poor; management fair.

Improvements.—We suggest that all gasoline and gasoline stoves be removed from building at once; fire buckets and water casks to be regularly attended to and kept full of water; one dozen additional fire buckets be distributed in galleries on hooks; all waste paper and sweepings be removed from building, and under stage not to be used for a general receptacle for waste paper, sweepings and rubbish.

And now, in conclusion, permit me to touch another point, which, however, I do with some diffidence. Being a resident of the fifteenth ward I am fully imbued with the positive general necessity of the proposed $6,000,000 boulevard to the park. We are all in accord with the movement to create additional breathing spots in our city, and to

expend a large sum of money to beautify the surroundings of the bourse. But where, permit me to ask, are we more in need of open spaces than around our places of amusement where thousands nightly congregate? The only way in which theatres can be made safe is to place them fronting broad streets not less than 60 feet wide, with wide open spaces on both sides not less than 20 feet—30 would be better in width.



Plan. View.

Then fire escapes, which are what the name implies, can be erected, and not arrangements the descent of which test the skill of an acrobat in broad daylight.

The best system of fire escapes is that of separated brick towers as introduced for permanent stairways in some of our well constructed manufactories. The above sections of a plan and bird's-eye view of one of our large local textile mills, shows how this is arranged, without requiring further verbal explanation.

I believe we have a right to require of our legislators that they prohibit the erection of additional fire-traps. But what shall we do with our present theatres? Force the

owners to make them safe as possible by ordinances or acts of Legislature, and let the city condemn the requisite adjoining properties, buy them, tear them down, and place breathing spaces on sides which are now without outlets. We never so long for a breath of fresh air as when in a building filled with smoke.

I have prepared ground plans of all the theatres of our city and surrounding properties. It will be seen on careful inspection of the plans before you, that the idea is not as extravagant as it appears at first utterance. Many of the theatres are at the intersections of streets needing but one side. The Board of Assessors could readily calculate what it would cost. The matter should be promptly acted upon. I believe, aside from the question of hazard from fire, it would be a good investment for the city. These spaces neatly kept, like little parks, would add much to the beauty of our municipality and would give the thousands who nightly attend our places of amusement, that greatest of all panaceas—pure air to breathe.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, June 21, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 21, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Present, nine members.

In the absence of the author, the paper of the evening, "On the Composition of the Liquid Ammonia of the Trade, and how to Manufacture Liquid Ammonia of 99·995 Per Cent.," by Dr. Hans von Strombeck, of New York, was read by the Secretary.

The paper was discussed by Messrs. Bower, Hall and Terne and was referred for publication.

Adjourned.

WM. C. DAY, *Secretary.*

ON THE COMPOSITION OF THE LIQUID AMMONIA OF THE TRADE AND HOW TO MANUFACTURE LIQUID AMMONIA OF REALLY 99·995 PER CENT.

BY DR. HANS VON STROMBECK.

[*Read at the stated meeting of the Chemical Section, June 21, 1892.*]

If the liquid ammonia of the trade, which is generally labelled and advertised as chemically pure anhydrous 100 per cent., is allowed to evaporate, a yellow fluid of peculiar penetrating odor and basic reaction is left in the bottle. This residue was left by any liquid ammonia which I subjected to the test, though they had been manufactured of different raw materials and by different processes. But the quantities left by different liquid ammonias were quite different. It is necessary to connect a long spiral cooler with the bottle in which the evaporation takes place and to

surround the cooler with a refrigerating mixture, as otherwise a large percentage of the yellow fluid is carried away by the evaporating ammonia. Sometimes also white needle-shaped crystals are left by the evaporating ammonia, which partly are deposited on the lower parts of the walls, partly swim on or are dissolved in the above-said fluid. These crystals consist of sesquicarbonate or hartshorn salt of ammonia $(NH_4)_2CO_3 + NH_4HCO_3$.

While this salt was present in every liquid ammonia analyzed, it did not appear in crystalline form every time. The basic reaction of the above-said yellow fluid is due to ammonia absorbed by the same. By supersaturation with dry muriatic acid, and removing the excess by quick-lime, a yellow neutral fluid is obtained. The yellow color is due to the presence of mineral (lubricant) oil. By distillation under reduced pressure, the latter can be separated out at 200 mm. pressure between 106° and 122° F., a colorless fluid being obtained in the receiver, while all the oil remains in the still. Besides by hartshorn salt of ammonia, by mineral oil and by "colorless fluid," as I shall call it in this paper, the liquid ammonia of the trade is contaminated by moisture and mineral matter suspended, the latter consisting of sand, peroxide of iron, etc. The mineral matter of sample B contained also sulphide of iron.

I give the analyses of six samples of so-called anhydrous liquid ammonia 100 per cent., manufactured of different raw material by different processes:

	A. *per cent.*	*B.* *per cent.*	*C.* *per cent.*	*D.* *per cent.*	*E.* *per cent.*	*F.* *per cent.*
Ammonia (by difference), .	98·976	96·984	98·220	99·792	99·321	99·180
Moisture, . . .	0·040	0·024	0·079	0·078	0·010	0·032
Colorless fluid,	0·950	2·880	1·644	0·117	0·622	0·666
Hartshorn salt of ammonia,	0·030	0·099	0·049	0·004	0·043	0·087
Lubricant oil, .	0·004	0·006	0·005	0·009	0·004	0·035
Mineral matter,	traces	0·007	0·003	traces	traces	traces
	100·000	100·000	100·000	100·000	100·000	100·000

The colorless fluid was further investigated. It has a specific gravity of 0·7948 at 60° F.; it is miscible with

water, burns with little luminous flame, has a specific odor reminding of alcohol and ketone. Subjected to distillation in fractions at atmospheric pressure (758 mm.), it yielded—

							Mainly consisting of
(1)	2·5 %	between	136°	and	153° F.	specific gravity at 60° F. 0·8048	methyl alcohol and acetone;
(2)	4·0	"	153°	"	165°	" " 0·8077	methyl- and ethyl-alcohol;
(3)	14·9	"	165°	"	172°	" " 0·8016	ethyl- alcohol;
(4)	78·6	"	172°	"	180°	" " 0·7901	isopropyl alcohol.

The reaction for ketones was also given by fraction No. 2; traces could also be detected in fraction No. 3. The ketones present can only be acetone and methylethylketone. Besides also traces of ethers may be present.

The composition of different colorless fluids is slightly different, but if any of them or one of its fractions is brought into contact with metallic sodium, the whole mass at once congeals to a more or less reddish powder, hydrogen at the same time being evolved, according to the equation:

Fraction 1. *Fraction 2.* *Fraction 3* *Fraction 4.*

(I) $CH_3.OH + CH_3.CO.CH_3 + CH_3.OH + C_2H_5.OH + C_2H_5.OH + CH_3.CH.OH.CH_3 + 2Na_2 =$

$CH_3.ONa + CH_2.CO.CH_2Na + CH_3.ONa + C_2H_5.ONa + C_2H_5.ONa + CH_3.CH.ONa.CH_3 + 2H_2$

As to the constitution of the sodium acetone compound which is only of theoretical interest, I refer to *Liebig's Ann. Chem., 1891, 266, 1.*

If we suppose the fractions containing two different bodies to consist of equal parts of each, and calculate the hydrogen which ought to be evolved by the decomposition of one part by weight of colorless fluid by metallic sodium, we find that 0·0179 parts by weight of hydrogen ought to be evolved. By test I found as average of four determinations that one part by weight of colorless fluid evolves 0·0166 parts by weight of hydrogen or ninety-three per cent. of the calculated quantity. Taking into consideration that the supposition on which the calculation was based is somewhat arbitrary, a better agreement can hardly be expected. As one part by weight of hydrogen requires twenty-three parts by weight of metallic sodium for its evolution, one pound of colorless fluid requires 0·38 pound of metallic sodium for its transformation into solid sodium compound.

A reaction similar to that between colorless fluid and

metallic sodium takes place between the latter body and two of the other above-mentioned contaminations of liquid ammonia, viz: Moisture and hartshorn salt of ammonia according to the equations.

(II) $2H_2O + Na_2 = 2NaOH + H_2$

and

(III) $[(NH_4)_2CO_3 + NH_4HCO_3] + 2Na_2 = 3NH_3 + 2Na_2CO_3 + 2H_2$

Based on the reactions which have been given in these three equations, I devised a process for the manufacture of liquid ammonia which on the average contains 99·995 per cent. of ammonia, 0·005 per cent. of mineral oil and nothing else (U. S. Patent 477,089), the removal of the oil being impossible because of its chemical nature. The process is as follows:

The ammonia gas which has been manufactured by one of the usual processes, and which has been already freed of the bulk of its moisture, instead of being directly drawn into the compressor, is first led through a vessel filled with molten metallic sodium. Here in this vessel the reactions described in the above three equations take place, whereby all contaminations present are transformed into solid non-volatile bodies and remain in this vessel, only ammonia gas and the hydrogen evolved escaping out of the same. The melting point of metallic sodium being at 204° F., it can easily be kept in a molten state by return steam which circulates through a jacket surrounding the vessel with the sodium. The ammonia is better led through two such vessels so as to make sure that all metallic sodium in the first one is exhausted before it is filled anew. By suitable connections the ammonia can be made to enter either vessel first or last. From the second vessel the now perfectly pure ammonia gas is drawn into the compressor and transformed into liquid in the usual way. From this description it will be seen that the apparatus required is of the simplest kind imaginable.

I first thought to bring the ammonia gas into contact with solid metallic sodium spread out on trays. But the reaction between the ammonia and the metallic sodium only

taking place as long as the surface of the latter is metallic, a somewhat complicated apparatus would have been required to meet this purpose. Knives and scoops would have had to be arranged in a drum in such a manner that the former continuously cut the metallic sodium to infinitesimally small pieces, while the latter carry them upward and drop them after they have reached an about perpendicular position, the ammonia gas thus having to pass through a constant shower of sodium with fresh metallic surfaces.

The hydrogen evolved is to be removed, as otherwise the engine working the compressor would have to perform useless work by the compression of the same. A very appropriate way to remove it is to have the purified ammonia gas and the hydrogen pass over palladium-black or palladium-gauze, each of which readily absorbs all hydrogen. Though palladium is a rather expensive article, one pound costing about $400, its expensiveness is counterbalanced by the fact that the same quantity of palladium can be used for an indefinite time. If heavily charged with hydrogen, it is only necessary to shut off by suitably arranged cocks the communication between the pipe filled with palladium and the rest of the plant and to lead atmospheric air through this pipe, whereby the palladium-black or gauze loses all hydrogen absorbed and is ready for use again. As one volume of palladium absorbs 800 volumes of hydrogen I do not think that even for a large plant more than one-half pound of palladium is required, as in the immensely finely distributed form in which it is used a small mass obtains an immensely large surface.

Now, let us see how much the cost caused by this purification process is. Let us make this calculation for an ammonia which, manufactured in the usual way, has the following composition, viz:

	Per Cent.
Ammonia,	98·976
Moisture,	0·040
Colorless fluid,	0·950
Hartshorn salt of ammonia,	0·030
Lubricant oil,	0·004
Mineral matter,	traces

Having above stated that one pound of colorless fluid requires 0·38 pound of metallic sodium, 0·36 pound of it is here required. One pound of metallic sodium costing $1.20, the quantity required costs forty-three cents. The metallic sodium required for the removal of each one hundredth of one per cent. of moisture costing 1·6 cents and that for the removal of each one hundredth of one per cent. of hartshorn salt costing 0·7 cents, the total expense for metallic sodium is fifty-two cents per 100 pounds of liquid ammonia. But 100 pounds of the ammonia in question yielding only 98·976 pounds of chemically pure ammonia, there is a loss of 1·024 per cent. The price of one pound of liquid ammonia being about thirty-five cents, this loss is equal to thirty-six cents. Or, the total increase of the manufacturing cost for 100 pounds is eighty-eight cents. But for this slight increase of cost we obtain a liquid ammonia which contains 99·996 per cent. of ammonia instead of the 98·976 per cent. as at present, and therefore will easily command a much higher market price.

In this calculation the sodium alcoholates resulting by the action of the metallic sodium on the colorless fluid are considered to be without any commercial value. But this is not so. By addition of water to the sodium alcoholates, and distilling with return steam the whole quantity of alcohols which was present in the raw material can be regained, and by introducing its market value into the calculation, the above stated increase of manufacturing cost will be considerably lessened.

While thus by my new process at a slight increase of cost liquid ammonia of 99·995 per cent. is obtained, the refrigerating power of which, is, of course, superior to that of the present commercial liquid ammonia, and thus the liquid ammonia sold as "strictly chemically pure anhydrous 100 per cent." really is what it is represented to be, there is still another point worthy of consideration. Every one connected with the refrigerating business knows of the terrific explosions which now and then occur in refrigerating plants, and for which heretofore no plausible cause could be given. While I cannot positively say how these explo-

sions originate, I should think that the presence of such inflammable bodies as alcohols and ketones point to where the cause for those explosions may be looked for. It is not at all necessary, or not even likely, that the alcohols, etc., in their present form cause the explosions, but after being decomposed into hydrocarbons, etc., the latter may do so. As answer to the question of how under the conditions given in a refrigerating plant, such a decomposition can take place, I would say that this can be done by the thermo-electricity developed by the ammonia condenser. The iron return bends being tightened to the iron pipes of such a condenser by means of tin solder; and, because of the current of the ammonia gas or liquid ammonia respectively through the condenser, the tin solderings on one side of the iron pipes being colder than the tin solderings on the other side of said pipes, and the end of the condenser where the liquid ammonia leaves the same, being connected by pipes with the end where the ammonia gas enters the same, all the conditions necessary for the development of thermo-electricity are given. The electro-motive force thus developed is, of course, only very small, but in the course of time enough hydrocarbons, etc., may be generated, which after being brought to explosion, may shatter the strongest iron pipe.

I intend to try to find out by experiment whether or not this supposition of mine be correct.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, May 31, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-two members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and lantern slides, which were approved and ordered paid.

The Committee on Admissions reported one election to membership since last meeting.

Mr. E. G. Willyoung described a series of experiments to determine the disturbing magnetic effect of so-called non-magnetic substances in sensitive measuring instruments. Out of a large list of substances experimented with, glass and paraffine were the only entirely non-magnetic ones.

Prof. Edwin J. Houston read a paper describing two methods of obtaining "A Graphic Representation of the Magnetic Field," illustrated by photographic prints and lantern slides. Referred for publication. In discussion thereon, Prof. Rondinella described two other methods that he had used for obtaining similar permanent records.

Mr. Carl Hering stated that he thought the iron filings method misleading, as in the strongest parts of the field the filings were often bunched in one spot, leaving another adjacent to it entirely bare. He preferred the method of investigating a magnetic field by means of a small freely-suspended magnet.

Prof. Edwin J. Houston read a paper on "The Physiological Effects of Alternating Currents of High Frequency." Referred for publication.

Mr. C. W. Pike described "The Disturbing Effects of External Magnetization upon the Weston Measuring Instruments." Referred for publication.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

EFFECT OF EXTERNAL MAGNETIC DISTURBANCES ON WESTON INSTRUMENTS.

CLAYTON W. PIKE,
Dept. Mechanical and Electrical Engineering, University of Pennsylvania.

[*Read at the meeting of Electrical Section, held May 31, 1892.*]

The Weston instruments are slight modifications of the well-known D'Arsonval galvanometer. In the voltmeter we have a pivoted fine wire coil turning between two poles of a permanent magnet, the restoring force being a pair of watch springs.

The action is as follows: When the terminals of the coil are connected to the points whose potential difference we wish to measure, a current flows through the coil proportional to this P.D. This current sets up lines of force and these acting upon the lines due to the permanent magnet cause a force which deflects the needle. It is evident that anything which permanently or temporarily changes the number of lines of force passing through the coil due to the permanent magnet will make the reading different from what it should be for a given P.D. at the terminals of the coil.

Owing to the difficulty of maintaining constant the strength of a powerful magnet, Mr. Weston employs a comparatively weak one, and hence we should naturally expect that comparatively small magnetic disturbances would affect the instrument.

In fact, the earth field exerts an appreciable influence and this fact is taken account of in the calibration of the instruments, although for commercial work the effect is too small to be of any account.

The effects to which I desire to call attention are those of the commercial or workshop order.

In many tests such as determination of the characteristic curve of a machine, the resistance of armature or fields, coëfficient of magnetic leakage, etc., two instruments are employed and the question comes up, how far apart must we put the two instruments so as not to affect each other appreciably.

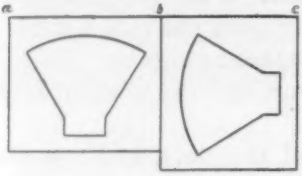
One of my students, Mr. J. A. Stewart, has made at my suggestion some quite extended experiments upon this point and finds that:

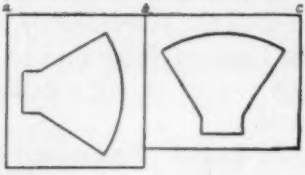
(1) A Weston instrument placed close to another may change its reading by about five per cent. The matter is then worth investigating.

(2) That as far as its disturbing influence goes, it makes practically no difference whether the disturbing instrument has current through its coils or not.

(3) That two instruments placed a foot apart from each other in any position do not affect each other's readings by one-fourth per cent.

It is often convenient, however, if one person is reading both instruments, to have them as close as possible, and Mr. Stewart showed that the best position was either of these two.

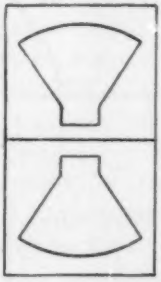




It is best that the points *a b c* should be in the same straight line.

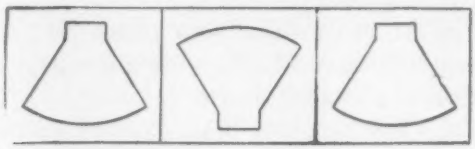
When this is the case neither instrument affects the reading of the other by as much as one-fourth per cent.

The maximum disturbance of five per cent. was reached as would be expected in this position.



We next wanted to find what effect would be produced by some things liable to occur in a workshop.

An ordinary twelve-inch file was placed in different position near a Weston instrument while measuring about half the amount possible. The file, when every part of it was at least four inches distant, produced practically no effect, but when placed thus, changed the deflection over four per



cent. An ordinary bench vise also acted just like the file, having no effect at four inches, but introducing an error of four per cent. when placed in position where it had its maximum effect.

The reason for this action is clear. Take the case of the file above. It evidently leads away from the coil a part of the lines of force due to the permanent magnet. There is then not so strong a deflecting force, and the reading is too small.

As to the effect of very powerful magnets, as those of a dynamo, we have not made sufficient experiments for publication.

Once in a while it is convenient to place three instruments together, and this arrangement gives an error of less than one-half per cent.

The observance, then, of very slight precautions, will allow us to place our instruments in any desired proximity without vitiating, to any appreciable extent, our results.

AMPÈRE-CENTIMETRE, A MEASURE OF ELECTRO-MAGNETISM.

By Carl Hering.

[*Read at the meeting of the Electrical Section held May 3, 1892.*]

It appears from the following deductions that an electric current multiplied by the length of the circuit will represent the number of magnetic lines of force generated by this current, or, in other words, that the number of lines of force generated by a current can be measured by the product of the current and the length of its circuit. A unit current passing through a unit length of circuit, appears to generate a certain fixed and constant number of lines of force. This, of course, has reference to the electro-magnetism of the current itself and does not include the influence of any magnetic bodies in the neighborhood.

First of all it is necessary to show that ampères multiplied by length will give a unit of a similar nature to magnetic lines of force or flux, in order to show that an equivalent between the two may be given without transgressing the laws of physics. This may be shown conclusively by the aid of the dimensions of these units in the absolute system. The dimension of current is $m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-1}$, while that of magnetic flux (that is, number of lines of force, not their density per square centimetre usually represented by H or B, nor the intensity as it is sometimes called), is $m^{\frac{1}{2}} l^{\frac{3}{2}} t^{-1}$. It will be seen that the former multiplied by a *length* gives the latter. This shows conclusively that ampère-centimetres, or ampère-feet and magnetic flux are units of the same kind and can therefore be equalled.

Having determined this point, the following appears to show that every unit length of a circuit conveying one ampère, generates a fixed and constant number of lines of force. Using absolute units, the intensity of magnetization (or number of lines per square centimetre) at the centre of

a circle of one turn, according to the well-known formula, is

$$H = \frac{2c\pi}{r}$$

in which r is the radius in centimetres and c is the current.

Now, the intensity of the field is different in different parts of the area enclosed by the circle, being greatest nearest to the wire, but it may be assumed that in all circles, large or small, the ratio of the intensity at the centre, to the average intensity in the whole circle, is a constant. Let this ratio be called K, then the total number of lines will be equal to the intensity at the centre multiplied by the area, and by K; that is,

$$M = \frac{2c\pi}{r} \times \pi r^2 \times K = 2c\pi^2 rK$$

By dividing this by the circumference will give the number of lines per unit length of the circuit

$$2c\pi^2 rK \div 2\pi r = C\pi K$$

or per unit of current, this is equal to πK. It will be seen that this is a constant and is *independent of the radius r*. This means that the number of lines per unit length and per unit current is the same for all circles, and therefore also for a straight line, which is a circle of infinite radius.

From this it appears that, knowing this constant number of lines per ampère per centimetre or foot, the calculation of the total number of lines generated by any circuit or coil, would merely be the product of the current, the length of the circuit, and a constant.

It should be remembered, however, that this deduction supposes theoretical conditions; that is, a filamentary wire having no appreciable diameter. How far the size of the wire introduces an error remains to be determined. At all events, if the diameter of the wire is small as compared with the diameter of the coil, and specially if the coil, as it usually does in practice, contains iron which appears to concentrate the lines in it, and therefore probably attracts those circulating in the body of the wire itself, it may doubtless be assumed that the ratio of the flux in two coils

would be equal to the ratio of their ampère-feet, which proportion might be of use in dynamo construction.

The above deductions were made by the writer a number of years ago, but as they did not appear to agree with some existing laws at that time, the matter was laid aside. It seems, however, that subsequently some dynamo builders have advocated and used this system of calculation in preference to the other, and it was therefore thought best to publish this proof, hoping that some others, well informed on this subject, might point out the discrepancies if any, and perhaps show the extent of the application in practice of calculating the magnetic flux of a current from the ampère-centimetres of the circuit.

THE PHYSIOLOGICAL EFFECTS OF ALTERNATING CURRENTS OF HIGH FREQUENCY.

BY PROF. EDWIN J. HOUSTON.

[*Read before the Electrical Section of the Franklin Institute, May 24, 1892.*]

GENTLEMEN:—I have concluded to place on record a brief statement of the substance of some remarks made by me at the last meeting of the section, concerning the physiological effects, on the human body, of alternating currents of very high frequencies.

As is well known, the physiological effects of alternating discharges of but moderate frequencies are more severe than are those of steady currents of the same current strength. As, however, the rapidity of alternation increases, the severity of the physiological effects decreases, until, at extraordinarily high frequencies, all harmful physiological effects practically disappear.

Three varieties of electric discharges or currents are employed in electrotherapy for the treatment of diseased conditions of the body.

(1) The steady, continuous currents produced by voltaic batteries, and called, in electrotherapeutics, Galvanic currents.

(2) The alternating currents produced by induction coils and called, in electrotherapeutics, Faradic currents.

(3) The electrostatic discharges obtained from frictional or influence machines and called, in electrotherapeutics, Franklinic currents.

As is well known, the physiological effects produced by Galvanic currents differ markedly from those produced by Faradic currents. The former, unless very powerful, produce on the opening or closing of the circuit, a contraction that is of very short duration—in fact almost but momentary; the latter produce a contraction that continues as long as the current is passing. This is generally believed to be due to the fact, that the contractions attending the opening and closing of the circuit, follow one another so rapidly that the muscles fail to assume the condition of rest and so present the appearance of continuous contraction.

Franklinic currents produce, in general, effects somewhat similar to those of Faradic currents.

When alternating currents are sent through the human body the physiological effects increase in severity with an increase in the current strength. With current strengths greatly in excess of those employed in electrotherapy additional effects are produced, and a tonic contraction of the muscles follow. Moreover, in such cases the severity of the physiological effects is increased by the high potential of the break-induced discharge.

As, however, the rapidity of alternation increases, the severity of the physiological effects decreases until, when enormously high frequencies are reached, the discharges become harmless. These facts have been demonstrated by Dr. Tatum for comparatively high frequencies, and by Nikola Tesla for enormously high frequencies.

In a lecture delivered before the American Institute of Electrical Engineers, at Columbia College, New York, on May 20, 1891, Tesla, speaking of these effects, says:

"I have found that by using the ordinary low frequencies, the physiological effects of the current required to maintain, at a certain degree of brightness, a tube four feet long, provided at the ends with outside and inside condenser

coatings, is so powerful that I think it might produce serious injury to those not accustomed to such shocks; whereas, with 20,000 alternations per second, the tube may be maintained at the same degree of brightness without any effect being felt.

"This is due principally to the fact that a much smaller potential is required to produce the same light effect and also to the higher efficiency in the light production. It is evident that the efficiency in such cases is the greater the higher the frequency, for the quicker the process of charging and discharging the molecules, the less energy will be lost in the form of dark radiation."

The severity of the physiological effects attending any electric discharge through the body must necessarily depend to a considerable extent not only on the quantity of energy present in the discharge, but also on the time in which it is acting.

It has occurred to me that in another circumstance is to be found, perhaps, the principal cause why discharges of enormously high frequency of alternation should be so comparatively harmless. This fact, I think, is to be found in the manner in which, according to our modern ideas, an electric discharge is believed to pass through a conducting path or circuit, viz: that the electric energy is not propagated through the mass of the conductor itself, but rather through the dielectric or other medium lying outside the conductor. That the electric energy is rained down on the surface of the conductor from the space outside it, and sinks down into the mass of the conductor, the conductor forming a sink or place where the energy can be dissipated.

In the case of a steady, continuous current, the energy sinks or soaks rapidly through the mass of the conductor, so that the electric current, in the language of the old ideas, passes through all portions of the mass of the conductor.

In the case of alternating currents, however, the energy received from a single impulse or electrical movement, by sinking or soaking moves (say) from the surface of the conductor towards the centre, only while such impulse con-

tinues; and, when the direction of the impulse changes, moves in the opposite direction, or towards the surface. In conductors through which alternating currents are passing, the current density is therefore greatest near the surface portions, and, in the case of alternations of very high frequency, the central portions of the conductor are entirely free from electric currents, the current being limited to portions near the surface.

In the case of the enormously high frequencies employed by Tesla, this action was so pronounced that conductors failed completely to conduct.

When, therefore, the human body is subjected to the effects of discharges of alternating currents of enormously high frequencies, the superficial portions only are traversed by the discharges. The more deeply seated, vital organs, being thus free from current, such discharges are necessarily harmless.

As the frequency of alternation increases, the body becomes more and more protected, until, when the frequency becomes as great as that of the ether waves, which cause sunlight, they would probably produce on the surface of the body the same genial effects as are produced by the light and heat of the sun, with which they are probably identical.

If these views are correct, it would appear that when the human body is exposed to rapidly-alternating discharges, it is subjected at one moment to a discharge that might produce instant death, were it not for the fact that the bolt is practically no sooner hurled at the body than it is hurled away from it.

A GRAPHIC REPRESENTATION OF THE MAGNETIC FIELD.

By Prof. Edwin J. Houston.

[*Read before the Electrical Section of the Franklin Institute, May 31, 1892.*]

Being engaged in a study of the magnetic field and desiring to obtain some simple method of fixing and readily reproducing the peculiarities of different fields, I have, after numerous trials, succeeded in devising a modification of an old and well-known plan, so simple and efficient, that I have thought it may be of sufficient interest to others engaged in similar investigations, to describe it in detail.

The method consists essentially in forming a magnetic field with iron filings on a plate of glass in the usual manner, and subsequently fixing the filings so as permit the plate to be used as a positive for obtaining a blue print, a silver print, a platinotype, or any other photographic print.

In order to readily fix the groupings of filings on the glass plate while in the field of the magnet, a thin film of wax is spread over one surface of the plate by any suitable process.

A convenient method of waxing the surface of the plate consists in first gradually heating the plate until its temperature is above that of the melting point of wax, and spreading melted wax over its surface by means of a brush. The surplus wax is then allowed to drain off the plate, or it may be wiped off by a piece of warmed paper. The remaining wax is then spread in an even film over the surface by cautiously heating the plate by a Bunsen flame or other suitable source of heat; or, the same thing can be effected by placing the plate in a vertical position in an oven or sand bath, supported on a suitable vessel so as to catch the surplus wax which drains off.

Plates can be readily covered in this manner with an uniformly thin coating of wax sufficiently transparent to permit them to be successfully employed for photographic

printing. For such purposes of course, only pure, white wax is employed.

The wax-covered glass plate so prepared is placed with its waxed surface upwards, in a horizontal position over the

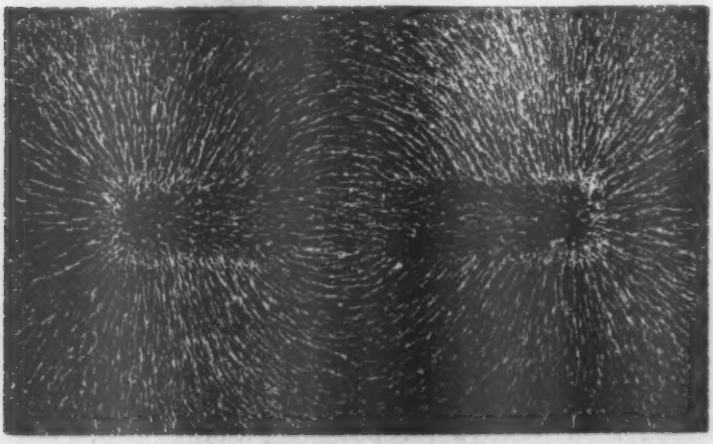


FIG. 1.—Field of bar magnets.

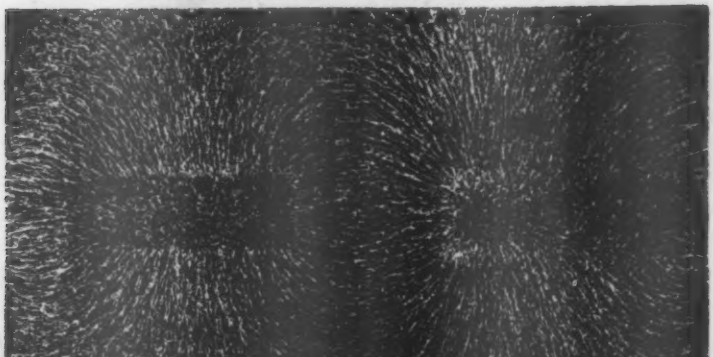


FIG. 2.—Opposite poles of bar magnets.

magnet whose field is to be fixed, and iron filings are sprinkled over its surface. The arrangement of the filings in the characteristic groupings of the field, is aided by gently tapping the plate in the usual manner.

When a satisfactory grouping of filings has been obtained, the field is fixed on the plate by gently warming it so as to melt the wax. At first I adopted the plan of carefully lifting the plate from the magnet and melting the wax by holding it over a source of heat, such as a Bunsen burner; but, no matter how carefully the plate was lifted from the magnet, or how nearly it was raised vertically from the same, so as to avoid lateral displacement of the filings, a change of figure almost invariably attended its removal. Better results were obtained when the wax was melted while the plate was in place over the magnet. This can readily be

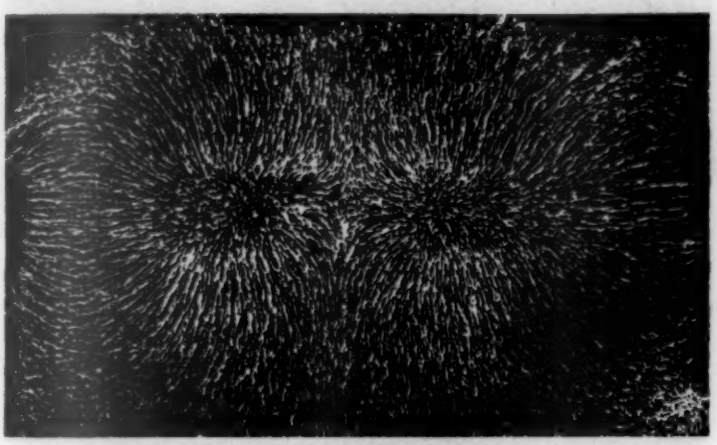


FIG. 3.—Similar poles of bar magnets.

effected either by holding a heated plate over the warm surface, or more conveniently by cautiously heating it by a Bunsen flame. After a slight heating, the flame may be permitted to play directly on the surface of the filings without displacing them.

After cooling, the plate with its fixed groupings of iron filings may be used as a positive for photographic printing. For this purpose it is placed in a printing frame with its surface of wax-fastened groupings of filings upwards, so as to come into contact with the surface of the sensitized paper.

If the plate has been properly prepared, but comparatively few filings will become detached from the waxed sur

face when it is brought into contact with the sensitized paper. These should be blown off before taking a second print from the plate.

In order to obtain the minimum of roughness of surface,

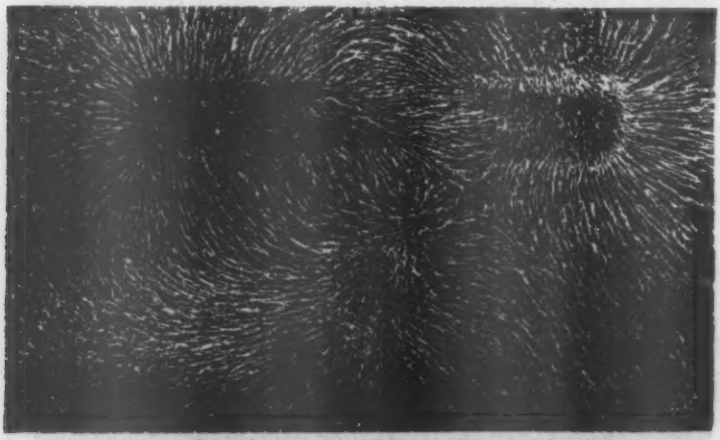


FIG. 4.—Bar magnets at right angles to each other.

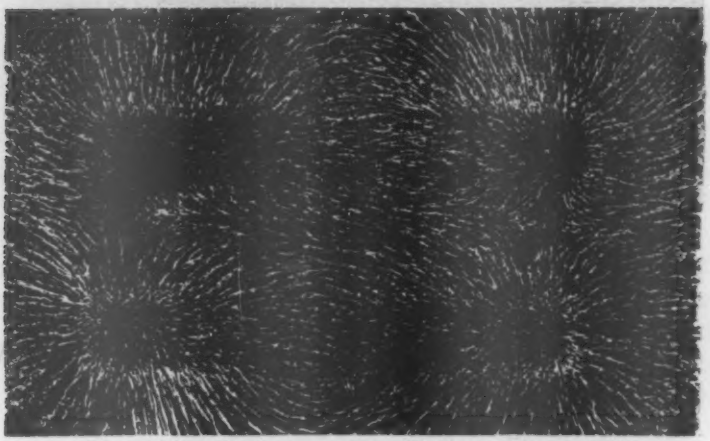


FIG. 5.—Parallel bar magnet. Similar poles opposed.

it is necessary to use filings that are as nearly as possible of a uniform size. This can be readily ensured by previously sieving them through a fine meshed wire gauze.

It is advisable that the plates be covered with as smooth a coating of wax as possible. Otherwise, the filings will be

prevented from readily arranging themselves in the directions which the lines of magnetic force pass.

In the case of powerful electro-magnets care must be taken to avoid a too great motion of the filings to the poles, since, in this manner, the portions of the surface over which the particles are moved, are swept clean of filings.

The best results are obtained by sieving the filings over the plate through a sieve whose meshes are sufficiently fine to ensure a small quantity only of filings falling on the plate at any one time. This, of course, is necessary to ensure the uniform distribution of the filings in the field of the magnet.

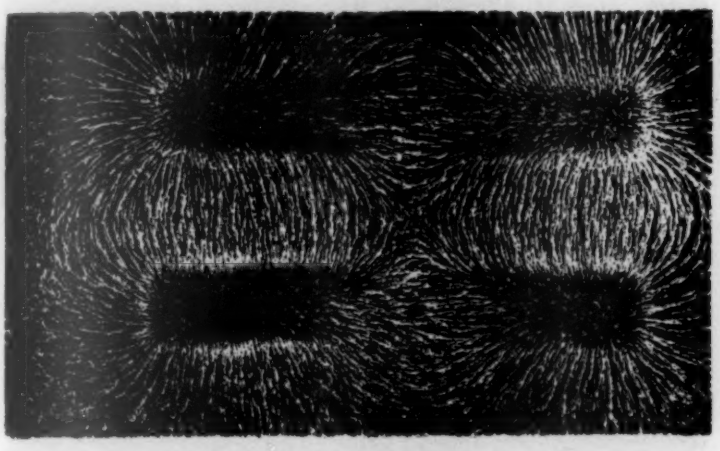


FIG. 6.—Bar magnets. Dissimilar poles opposed.

When the plates on which the magnetic fields are so fixed, are used for positives for photographic reproduction, and negative prints obtained therefrom in black, as by means of a silver print, or a platinotype, such prints can readily be used for the purposes of graphic reproduction for printing by any of the well-known photographic processes. In this way cuts and illustrations of actual fields can be readily had for purposes of illustration, without the introduction of those well-known errors arising from the too great artistic imagination of the copyist.

For purposes of subsequent reproduction I find platino-

type paper the best, as it gives dead blacks, that contrasting markedly with the white lines and spaces occupied by the iron fillings are readily photographed by any of the well-known processes of reproduction.

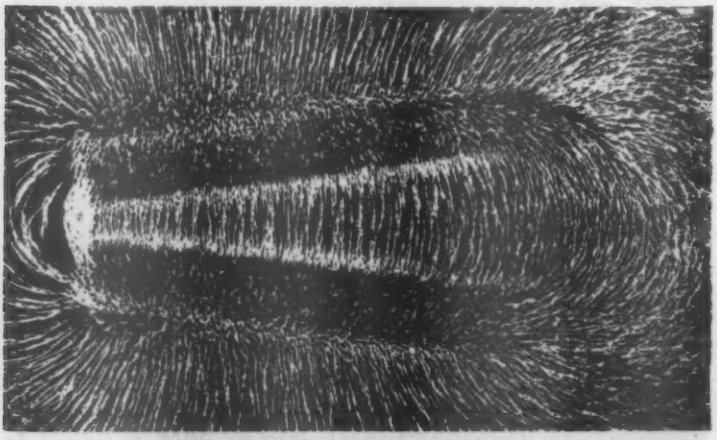


FIG. 7.—Field of horseshoe magnet.

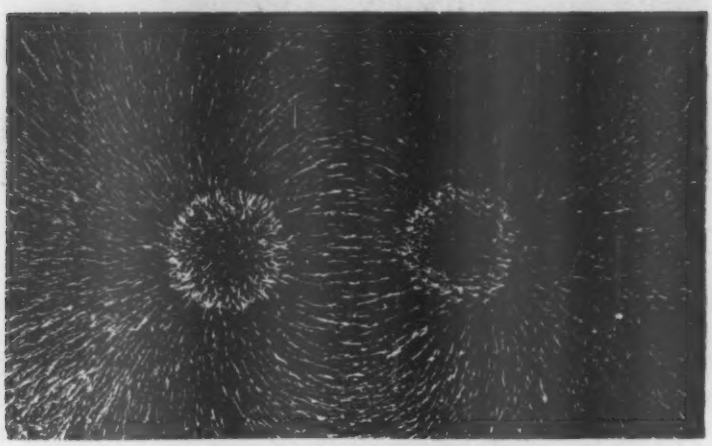


FIG. 8.—Field of electro-magnet.

When the filings are dusted over the plate from a sieve held a few feet above the waxed surface rather than quite near its surface, a better grouping of the filings is obtained.

I have prepared a number of fields according to the pro-

cesses described. They have been printed by the platinotype process.

In *Fig. 1*, is shown the field of a straight bar magnet. The characteristic radiation of the lines of force at the poles is well shown, as well as the curved lines produced by the mutual attraction of the lines coming out of the north and proceeding towards the south pole. The numerous parallel lines at the equator of the magnet show the strength of the magnetic flux at that point.

Fig. 2, shows the field produced by the approached, unlike poles of two straight bar magnets. The attraction of the

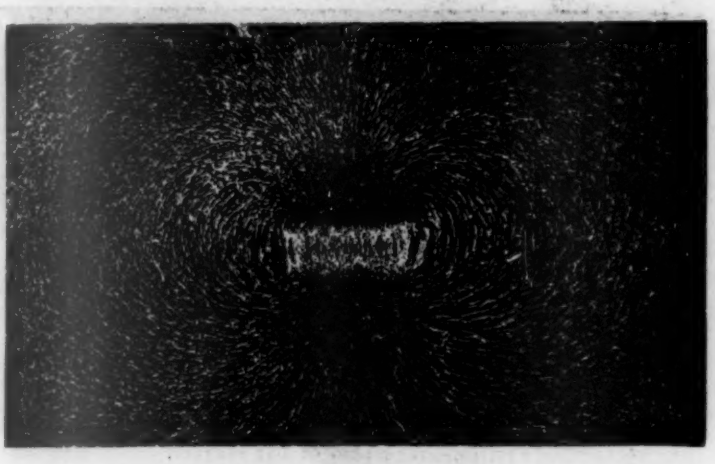


FIG. 9.—Field of permanent horseshoe magnet.

oppositely directed lines of force in the space between the opposing poles, as well as the increase in the length of space on the bars from which the lines pass off approximately at right angles to the surface, are well marked.

Fig. 3, shows the field produced by the approached, similar poles of the same straight bar magnets used in *Fig. 2*. The repulsion of the similarly directed lines of force producing nearly straight paths in lines at right angles to the length of the magnet, as well as a curious space midway between the poles, bounded by apparently hyperbolic curves are clearly seen.

Fig. 4, shows a very curious field produced by two bar magnets placed with their axes at right angles to each other so that one of the poles of one magnet is placed at right angles to the neutral point of the other and at a short distance from it. At the left-hand of the field is shown the curved deflections of the lines of force produced by the attractions of opposite poles. The lines of force coming out of a north pole and those entering at a south pole mutually attract one another and produce curves similar to those shown in the space between the approached, opposite poles shown in *Fig. 2*. At the right-hand of the field the repul-

FIG. 10.—Wire field of bar magnet.

sions existing between the similarly directed lines of force produce characteristic parallel streamings. The curious area bounded by hyperbolic curves is shown in the space between the poles at the right of the figure.

Fig. 5, shows the field produced by two straight bar magnets placed with their axes parallel to each other and their similar poles near together. The mutual repulsions of their fields are clearly shown. The curious areas bounded by hyperbolic curves are shown in the spaces at each end between the poles of the magnets.

Fig. 6, shows the field produced by the same parallel bar magnets placed with their opposite poles near together.

The attraction of their oppositely directed lines of force is well marked. In the neighborhood of their neutral points, a very marked area bounded by hyperbolic curves is seen. The strength of the magnetic flux near the neutral points is also marked.

Fig. 7, shows the field of an ordinary horseshoe magnet. The magnetic leakage between the sides of the bar is marked, as is also the strength of the magnetic flux in the neighborhood of the equator or neutral point of the magnet.

Fig. 8, shows the field of an electro-magnet. In order to

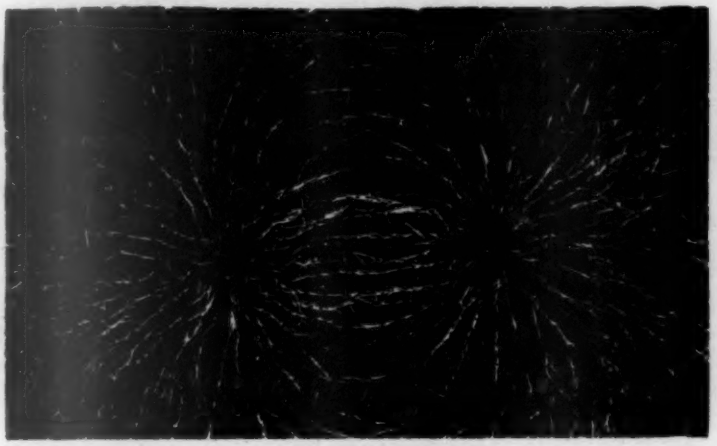


FIG. 11.—Wire field of electro-magnet.

avoid the injurious sweeping action of the particles as they are carried bodily forward towards the poles, I found it necessary to use a very weak current, and to place the plate a short distance above the poles.

It may be mentioned in this connection that it is in general advisable to avoid resting the plate on the surface of the magnet, since when the plate does not touch the poles it is left free to be gently tapped or vibrated so as to permit the filings to arrange or group themselves while in the field of magnet.

Fig. 9, shows the field of a peculiarly shaped permanent

horseshoe magnet taken in a plane over the poles at right angles to the length of the magnet. I was rather surprised in this case to find that so many of the lines of force passed through extended air circuits shown rather than through the narrow gap directly between the poles.

Fig. 10, shows a novel field obtained by short lengths of very thin iron wire, that act as small magnetic needles. The field is that of the bar magnet employed in *Fig. 1*. Although the separate particles do not possess as great freedom of motion as the shorter and smaller iron filings, yet their tendency to come to rest with the lines of magnetic

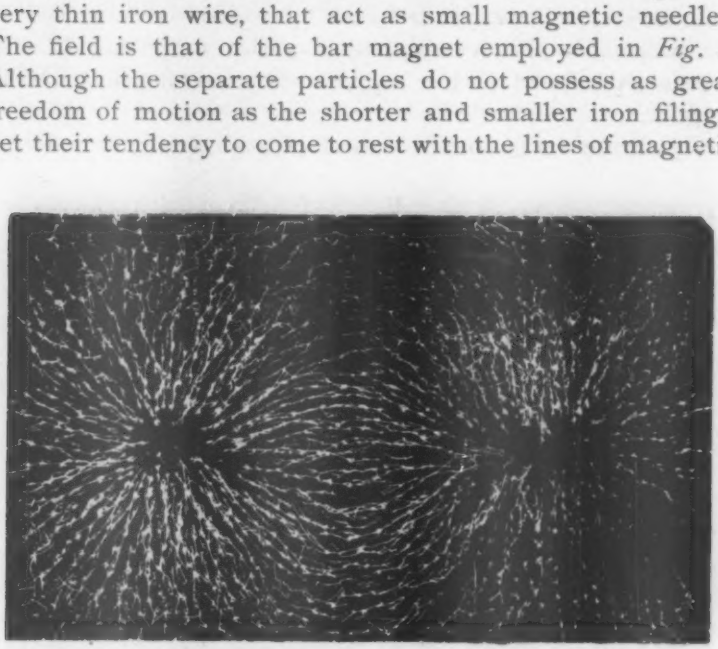


FIG. 12.—Wire and filings field.

force passing through their greatest dimensions, so as to reduce the resistance of the magnetic circuit as much as possible, is manifest.

The peculiar wire field produced by these means is of especial interest when studied in the light of Ewing's theory of magnetism.

Fig. 11, shows another wire field produced by the same electro-magnet as is employed in *Fig. 8*. The polarization of the minute magnetic needles and their arrangement in groupings of polarized chains is well marked.

Fig. 12, shows a field produced by iron filings and iron

wire. The peculiar groupings of the iron wire in chains of polarized particles are clearly shown.

A curious resemblance is possessed by this field and other wire fields to the discharge produced by a lightning flash, or other high potential discharge; such, for example, as the recent 500,000 volt discharge of Elihu Thomson. This resemblance quite naturally leads to the speculation, whether the peculiar forked or curved shapes of such discharges are not due to similar causes, viz: to polarized chains of particles of the medium which offers paths of less resistance to the discharge than the spaces adjoining or surrounding them.

I am making some experiments in solid fields, *i. e.*, in the peculiarities of the distribution of the lines of force in the space of three dimensions surrounding magnets, which I trust to be able shortly to bring before you.

I desire to express my indebtedness to my assistant, Mr. B. F. Lacy, for valuable aid in preparing the plates.

Since writing the above my attention has been called to the fact that the process above described has been very fully anticipated by Prof. Mayer, in a publication printed in the *Journal of the Franklin Institute*, for May, 1871. As my process differs in some particulars from that described by Prof. Mayer, and as it appears to me advisable to call attention to both processes at this time, I have concluded to permit the paper to go to publication. To Prof. Mayer, however, the credit is due for the first conception of the general process.

Since writing the above on last Saturday, I have devised a new plan which I believe to be far in advance of what I have just described.

According to this plan I place a dry sensitized photographic plate over the magnet whose field I desire to fix and after the characteristic groupings of filings have been obtained, I expose such plate while over the magnet to the light of a gas flame for a few seconds.

This operation is necessarily performed in the dark photographic room. After exposure the light is turned out and only the non-actinic red or yellow light left. The filings are allowed to fall off the surface of the dry plate, and the

finer particles that still adhere to it are brushed off by a feather or dry camel's hair brush. The plate is then developed and fixed in the usual manner.

The removal of the adherent iron dust by the feather or brush is preferable to the use of the breath, as this is apt to produce troublesome spots.

I have found that the so-called lightning gelatine dry plates give very satisfactory results when employed for such purposes.

This process of obtaining records of magnetic fields produces true negatives, which when employed for printing by blue print, silver print, platinotype, or similar process produce excellent positives.

As the negatives so obtained are more permanent than the positives obtained by the use of the filings themselves, they permit the taking of an indefinite number of photographic prints.

I have thought of forming the field directly on the surface of sensitized paper and exposing such to light. But such paper is apt to curl, and such processes produce but a single impression.

The time has been too short to prepare many specimens of fields by this new process. I hope to be able, however, by the next meeting of the section, to present such results in a short paper.

BOOK NOTICES.

Appleton's School Physics, embracing the results of the most recent researches in the several departments of natural philosophy. By Profs. Quackenboss, Mayer, Nipher, Holman and Crocker. New York, Cincinnati, Chicago: American Book Company. (From the press of D. Appleton & Co. N. D.) Price, $1.20.

A work prepared by a half-dozen different hands might be expected naturally to exhibit some unevenness on this account. The present volume, however, so far as we have had the opportunity of examining it, appears to be in all respects admirably prepared and well adapted for its intended purpose of serving as an elementary text book. In its treatment of first principles, it is fully abreast with the most advanced conceptions of the leaders of modern thought and the method of presenting abstruse subjects is characterized by a clearness that is as satisfying as it is rare in works of its class. W.

The Ventilation of Buildings. By Alfred R. Wolff, M. E., Member Am. Soc. Mech. Engrs., etc. (Second Edition.) New York: Author, Potter Bldg. N. D. Price, 25 cents.

The extended notice of this excellent paper, which appeared in the *Journal* about a year ago, renders it unnecessary for us to do more than call attention to the appearance of a second edition. There is no better general treatment of the subject in the language within such compact limits as these 32 octavo pages, and if the author could be persuaded to elaborate the paper, so as to discuss at length the special systems used and with suitable illustrations, its usefulness would be greatly increased, without sacrifice of its technical merits. W.

Les Theories Modernes de l'Électricité. Essai d'une theorie nouvelle. Par O. Lodge. F.R.S., etc. Traduit de l'Anglais et annoté par E. Meylan, ingénieur civil, etc. II vols. 8vo, with figures in the text. Paris: Gauthier-Villars et Fils. 1891. (Price, 5 francs.)

This translation of the work of Lodge, so well known to English-reading students of electricity, appears to be the first attempt to place before French readers, in their own language, the modern conception of electricity and magnetism, as in some direct manner an affection of the lummiferous ether, which is entertained and advocated by Maxwell, Sir Wm. Thomson and other leaders of scientific thought. The translator has performed his task with fidelity and his intelligent annotations of the original text add notably to the value of the translation. W.

Report of Committee on Disposal of Waste and Garbage, presented at the Nineteenth Annual Meeting of the American Public Health Association, Kansas City, October 20–23, 1891. Concord, N. H.: Republican Press Association. 1892.

This report will be found specially valuable to city engineers, municipal authorities and sanitary engineers. It contains, among other valuable information, a *résumé* of the practice of a large number of American cities in relation to the disposal of waste and garbage, an excellent paper giving valuable hints on this important subject, and some interesting data embodying foreign experience in solving the problem. W.

Modern Practice of the Electric Telegraph. A technical hand-book for electricians, managers and operators, with 185 illustrations. By Franklin Leonard Pope. (Fourteenth edition, rewritten and enlarged.) New York: D. Van Nostrand Company. London: Sampson, Low, Marston & Co. 1891.

The author has appreciated the fact that the unparalleled progress within the past ten years in all that pertains to the application of electricity to the industrial arts, has also materially affected the theory and practice of the electric telegraph. He has recognized the fact by preparing, not a new edition of his standard work, but, substantially, a new book, in which the principles and practice of the electric telegraph from the modern standpoint are most thoroughly explained and illustrated. W.

The Separate System of Sewerage. By Cady Staley and Geo. S. Pierson. (Second edition.) New York: D. Van Nostrand Company. 1891.

The first edition of this work was reviewed in our issue of September, 1887, and we can only add to the favorable comments then made, by saying that the present edition contains nearly 100 additional pages, the perplexing and important question of sewage disposal being treated in a manner which increases the value of the work. W. B. C.

ERRATUM.

Book Notices, June, 1892, on line 7, p. 503, for "decreased" *read* "increased."

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 15, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 15, 1892.

JOS. M. WILSON, President, in the chair.

Present, 128 members and eight visitors.

Additions to membership since last report, seven,

The actuary submitted a resolution of the Board of Managers referring to the Institute a communication from Mr. Alex. De Beaumont, in which he requested to be accorded the privilege of being reinstated as a member. The Secretary thereupon presented Mr. De Beaumont's communication, and on motion of Mr. H. R. Heyl, it was resolved, in view of the statements contained in the said communication that Mr. De Beaumont be accorded the privilege of reinstating himself as a member of the Franklin Institute.

Mr. Pedro G. Salom read a paper on the "Present Status of the Storage Battery System of Electric Street Railway Propulsion." (Referred for publication.)

A paper of Dr. Wellington Adams, entitled "From Chicago to St. Louis by Electric Express," which was announced for the evening, was deferred on account of a despatch from Dr. Adams, announcing his unavoidable absence.

Mr. S. Lloyd Wiegand described and illustrated certain improvements in the manufacture of artificial limbs, devised by the brothers Marks, of New York, which involved the application of aluminum. On motion of Mr. W. M. McAllister, the subject was referred to the Committee on Science and the Arts.

The Secretary presented a brief report, and Mr. W. N. Jennings made an exhibition of a number of photographic pictures of local interest.

Adjourned. WM. H. WAHL, *Secretary.*